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The design, development, implementation and evaluation of Project FLAME: A multi-component, school-based, motor competence intervention for adolescent youth in Ireland

Thesis presented by

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Declaration

"This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism."

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Diarmuid Lester

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Abstract

The design, development, implementation and evaluation of Project FLAME: A multi-component, school-based, motor competence intervention for adolescent youth in Ireland.

Diarmuid Lester

Background: Recent research has shown that Irish adolescent youth are insufficiently active and fail to reach basic levels of fundamental movement skills (FMS) and functional movement. Schools and the engagement of relevant stakeholders, particularly qualified Physical Education (PE) specialist teachers, are key vehicles for the provision of movement-based opportunities in youth. The purpose of the first phase of this research was to gather cross-sectional data on adolescent youth, differentiated by gender and grade across the first three years (Junior Cycle) of post-primary education, specifically to inform the development a multi-component, school-based motor competence intervention entitled Project FLAME (Fundamental and Functional Literacy for Activity and Movement Efficiency). The second phase of the research aimed to evaluate if Project FLAME can improve FMS and functional movement in adolescent youth.

Methods: Cross-sectional data, as part of the first phase of the research, were collected on adolescents (N = 219; mean age: 14.45 ± 0.96 years), within two, mixed gender schools. Primary outcome measures were consistent in both phases of the research and included the assessment of ten FMS (including locomotor and object control subsets) in conjunction with the observable, behavioural components from three established testing batteries, namely the Test of Gross Motor Development (TGMD), TGMD-2, and the Get Skilled: Get Active manual, as well as the seven tests within the Functional Movement Screen (FMS™). The Project FLAME intervention included four major components, specifically the i) specialist Physical Education (PE) teacher component, ii) kinaesthetic classroom component, iii) student component and iv) digital literacy component. Using a non-randomized controlled trial as part of the second phase of the research, a target sample of 363 participants (56% male, mean age: 14.04 ± 0.89 years old) were recruited from three mixed-gender, sub-urban schools (two intervention; one control) in Cork, Ireland, for baseline data collection, followed by a 13-week consecutive intervention roll out, and post-test data collection. Linear mixed models were used to assess the effect of the intervention with two main effects, treatment and time, and their interaction. Analyses were adjusted for participants' gender, age, grade and BMI score.

Results: Based on the results from the cross-sectional data, levels of actual mastery within FMS and functional movement were low, with significant gender and age-related differences observed. Following the implementation of the Project FLAME non-randomized controlled trial, significant intervention effects across time were observed, with the greatest improvements evident for overall gross FMS (p = .002).

Discussion: Findings from the first phase of the research suggested that developing a multi-component, school-based intervention was a strategic step that could improve the observed low levels of adolescent FMS and functional movement. The Project FLAME intervention was successful at improving adolescent overall FMS gross motor competence, resulting in significant treatment-time interactions. A whole-

school approach emphasising FMS and functional movement, which include developmentally appropriate activities, and the concurrent involvement of specialist PE, and non-specialist PE teachers appears effective for developing motor competence in adolescent youth.

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1.1 Publications and Conference Proceedings

Journal Articles – Published

Lester, D., McGrane, B., Belton, S., Duncan, M. J., Chambers, F. C., & O'Brien, W. (2017). **The age-related association of movement in Irish adolescent youth.** *Sports*, *5(4)*, 77. DOI: http://doi.org/10.3390/sports5040077

O'Brien, W., Duncan, M. J., Farmer, O., & **Lester, D.** (2018). **Do Irish adolescents have adequate functional movement skill and confidence?** *Journal of Motor Learning and Development*, *6(s2)*, S301-S319. DOI: http://doi.org/10.1123/jmld.2016-0067

Farmer, O., Duffy, D., Cahill, K., **Lester, D.**, Belton, S., & O'Brien, W. (2018). **Enhancing the evidence base for Irish female youth participation in physical activity – The development of the Gaelic4Girls program.** *Women in Sport and Physical Activity Journal*, *26(2)*, 111-123. DOI: https://doi.org/10.1123/wspaj.2017-0046

Philpott, C., Donovan, B., Belton, S., **Lester, D.**, Duncan, M., Chambers, F., & O'Brien, W. (2020). **Investigating the age-related association between perceived motor competence and actual motor competence in adolescence.** *International Journal of Environmental Research and Public Health*, *17(17)*, 6361. DOI: https://doi.org/10.3390/ijerph17176361

Journal Articles – Under Review

Lester, D., Belton, S., Duncan, M. J., & O'Brien, W. (2020). **Rationale and study protocol for the Project FLAME non-randomized controlled trial: A multi-component, school-based, motor competence intervention for adolescent youth.** *Physical Education and Sport Pedagogy*.

Lester, D., Utesch, T., Belton, S., Duncan, M. J., Bolger, L. E., Chambers, F. C., & O'Brien, W. (2020). **A school-based intervention to improve functional movement and fundamental movement skills in adolescent youth: Evaluating the effectiveness of Project FLAME.** *Physical Education and Sport Pedagogy*.

O'Brien, W., **Lester, D.**, Belton, S., Duncan, M. J., Philpott, C., Donovan, B., Chambers, F., & Utesch, T. (2020). **Motor competence assessment in physical education – Convergent and divergent validity between fundamental movement skills and functional movement assessments in adolescence.** *Physical Education and Sport Pedagogy*.

Oral Presentations

Lester, D., Belton, S., Chambers, F. C., & O'Brien, W. (January 2020). Evaluating the effectiveness of the Project FLAME non-randomized controlled trial: A multi-component, school-based motor competence intervention for adolescent youth in Ireland. *Network Meeting 3: Children's motor competence and its impact on physical activity, exercise, sport and health*, Liverpool John Moores University, Liverpool, United Kingdom.

Lester, D., Chambers, F. C., Belton, S., & O'Brien, W. (September 2019). The rationale and effectiveness of Project FLAME: A multi-component, school-based motor competence intervention for adolescent youth in Ireland. *International Motor Development Research Consortium (I-MDRC)*, Verona, Italy.

O'Brien, W., **Lester, D.**, Donovan, B., Philpott, C., Duncan, M., & Belton, S. (September 2019). Putting a focused lens on Irish adolescent movement skill proficiency. *International Motor Development Research Consortium (I-MDRC),* Verona, Italy.

O’Brien, W., Chambers, F. C., Belton, S., & **Lester, D.** (September 2019). Rationale and study protocol for the Project FLAME non-randomized controlled trial: A multi-component, school-based motor competence intervention for adolescent youth. *European Conference on Educational Research (ECER)*, Hamburg, Germany.

Lester, D., Belton, S., Duncan, M. J., & O’Brien, W. (June 2019). The effectiveness of Project FLAME: A multi-component, school-based motor competence intervention for adolescent youth in Ireland. Motor Competence in Childhood: The forgotten pathway to improved cardiovascular health, Coventry University, Coventry, United Kingdom.

O’Brien, W. & **Lester, D.** (May 2019). A motor competence approach to school-based physical literacy promotion for Irish adolescents. *International Physical Literacy Conference (IPLC)*, Winnipeg, Manitoba, Canada.

Lester, D. & O’Brien, W. (January 2019). Study protocol for the Project FLAME non-randomized controlled trial. *Network Meeting 2: Children’s motor competence and its impact on physical activity, exercise, sport and health*, University College Cork, Cork, Ireland.

Lester, D. & O’Brien, W. (November 2018). Intervention process and preliminary findings of Project FLAME. *Physical Education, Physical Activity and Youth Sport (PEPAYS) Ireland Annual Forum*, University of Limerick, Limerick, Ireland.

Lester, D. & O’Brien, W. (January 2018). Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency. *Network Meeting 1: Children’s motor competence and its impact on physical activity, exercise, sport and health*, Coventry University, Coventry, United Kingdom.

Lester, D. & O'Brien, W. (June 2017). Differences in 'fundamental' and 'functional' movement according to gender and age within an Irish adolescent school-based population. *Physical Education, Physical Activity and Youth Sport (PEPAYS) Ireland Annual Forum*, University of Limerick, Limerick, Ireland.

Lester, D. & O'Brien, W. (December 2016). Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency. *College of Arts, Celtic Studies and Social Sciences (CACSSS) Postgraduate Research Conference*, University College Cork, Cork, Ireland.

Lester, D. & O'Brien, W. (September 2016). Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency. *Children's Research Network for Ireland and Northern Ireland, PhD Symposium*, Maynooth University, Maynooth, Kildare, Ireland.

Lester, D. & O'Brien, W. (September 2016). Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency. *Health-Enhancing Physical Activity (HEPA) Europe Conference*, Belfast, Northern Ireland.

Lester, D. & O'Brien, W. (June 2016). Background and methodological considerations in the development of an Irish youth movement programme. *International Society of Behavioral Nutrition and Physical Activity (ISBNPA) Conference*, Cape Town, South Africa.

Lester, D. & O'Brien, W. (May 2016). Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency. *Physical Education, Physical Activity and Youth Sport (PEPAYS) Ireland Annual Forum*, IT Tralee, Tralee, Kerry, Ireland.

Lester, D. (May 2016). Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency. *Postgraduate Research Showcase, Grand Plan Category (Year 1 PhD Students)*, University College Cork, Cork, Ireland.

Lester, D. & O’Brien, W. (April 2016). Background and methodological considerations in the development of an Irish youth movement programme. *All-Ireland Postgraduate Conference in Sports Sciences, Physical Activity and Physical Education*, Waterford IT, Waterford, Ireland.

Lester, D. & O’Brien, W. (December 2015). Rationale and proposed study protocol for an Irish youth movement programme. *College of Arts, Celtic Studies and Social Sciences (CACSSS) Postgraduate Research Conference*, University College Cork, Cork, Ireland.

Poster Presentations

Lester, D. & O’Brien, W. (October 2018). The implementation and effectiveness of Project FLAME: A multi-component, school based, movement intervention in Ireland. *International Society for Physical Activity and Health (ISPAH) Conference*, London, United Kingdom.

Lester, D. & O’Brien, W. (June 2018). The development of Project FLAME – a multi-component, school based movement intervention for adolescents in Ireland. *North American Society for the Psychology of Sport and Physical Activity (NASPSPA) Conference*, Denver, Colorado, USA.

Lester, D. Chambers, F. C., McGrane, B., & O’Brien, W. (June 2017). Gender related differences in ‘fundamental’ and ‘functional’ movement within an Irish adolescent school-based population. *International Society of Behavioural Nutrition and Physical Activity (ISBNPA) Conference*, Victoria, British Columbia, Canada.

Lester, D. & O’Brien, W. (January 2017). Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency. *Gaelic Athletic Association (GAA) Games Development Conference*, Croke Park, Dublin, Ireland.

Conference Workshops

Lester, D. & O'Brien, W. (October 2018). The Kinaesthetic Classroom: Movement Breaks with a Purpose in the Post Primary Classroom. *Physical Education Association of Ireland (PEAI) Annual Conference*, Scoil Chríost Rí, Port Laoise, Laois, Ireland.

O'Brien, W., Farmer, O., McGrane, B., & **Lester, D.** (June 2017). Fundamental and functional movement literacy – the provision of meaningful childhood physical activity experiences. *International Society of Behavioral Nutrition and Physical Activity (ISBNPA) Conference*, Victoria, British Columbia, Canada.

Invited Speaker

Lester, D. & O'Brien, W. (February 2020). The importance of fundamental movement skills for children. *Rebel Óg Coaching Conference*, Nemo Rangers GAA Complex, Cork, Ireland.

1.2 Introduction to Thesis

1.2.1 The Background

According to the World Health Organization (WHO), physical inactivity has been identified as one of the leading risk factors for global mortality (World Health Organization, 2018c). Currently, more than 80% of the world's adolescent population are insufficiently physically active, with global findings showing that 81% of 11 to 17 year olds are failing to meet the recommended physical activity (PA) guidelines for health (i.e., 60 minutes of moderate-to-vigorous physical activity (MVPA) per day) (World Health Organization, 2010, 2013, 2018a, 2018c). Previous data obtained from 105 countries worldwide has also highlighted a consistent trend, with 80% of adolescent youth aged 13 to 15 years old failing to meet the recommended PA guidelines (Hallal et al., 2012).

The prevalence of overweight and obesity among children and adolescents (aged 5 to 19 years old) has also risen dramatically, most notably from just 4% in 1975, to just over 18% in 2016 (World Health Organization, 2018b). To put this into context, over 340 million children and adolescents aged 5 to 19 years old were overweight or obese in 2016. This rise has occurred similarly among both boys and girls, for example, in 2016, 18% of girls and 19% of boys were deemed to be overweight (World Health Organization, 2018b). Furthermore, while just under 1% of children and adolescents were obese in 1975, more than 124 million children and adolescents (6% of girls, and 8% of boys) were classified as obese in 2016 (World Health Organization, 2018b).

Ireland is on course to become one of the most physically inactive and obese nations in Europe in the next decade (NCD, 2016; Webber et al., 2014), as confirmed by the recent 'Children's Sports Participation and Physical Activity' (CSPPA) study (Woods et al., 2018), Ireland's largest nationally representative research on childhood PA surveillance. This study observed that 17% of children and only 10% of adolescents achieve the recommended levels of PA for health. These findings support the Health Behaviour in School-aged Children (HBSC) study (Inchley et al., 2016), which observed that the daily MVPA of boys and girls in over thirty countries and regions decreases significantly between 11 and 15 years of age (Inchley et al., 2016; Janz, Dawson, & Mahoney, 2000; Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). Furthermore, childhood obesity figures from a sub-sample of participants (n = 1,325, 48% male; average age: 13.3 $\pm$ 1.5 years) in the recent CSPPA study revealed that one in four Irish children are now classified as overweight (20%) or obese (6%) (Woods et al., 2018).

In light of these national and indeed global health concerns; researchers, practitioners, teachers and other key stakeholders are constantly seeking to counteract the dramatic decline in adolescent levels of PA participation, as well as the onset of noncommunicable diseases (NCDs) (e.g., diabetes). In 2013, for example, the WHO launched the 'Global Action Plan for the Prevention and Control of NCDs 2013-2020', which called for a 10% reduction in physical inactivity by 2025 (World Health Organization, 2013). More recently in 2018, the WHO launched the 'Global Action Plan on Physical Activity 2018-2030' with the vision of seeing 'more active people for a healthier world' (World Health Organization, 2018a). This document targets a 15% relative reduction in the global prevalence of physical inactivity in adults and in adolescents by 2030 (World Health Organization, 2018a). In January 2016, the Government launched Ireland's first ever 'National Physical Activity Plan (NPAP)', which aims to get at least half a million more Irish people participating in regular exercise within ten years (Healthy Ireland, 2016a, 2016b). The area of 'motor development' is one mechanism that has gained significant interest internationally, specifically as a strategy to combat the societal concerns for adolescents, as mentioned above.

Research would suggest that providing children and youth with the "*tools to be physically active*" (Butterfield, Angell, & Mason, 2012, p.261), they have greater potential to benefit their current and future health (Belton, O'Brien, Meegan, Woods, & Issartel, 2014; Gallahue, Ozmun, & Goodway, 2012). The promotion of motor competence is an integral strategy in holistically viewing children's development (Barnett et al., 2016; Estevan & Barnett, 2018; Robinson et al., 2015). Motor competence is seen as a strategic supplement in the promotion of PA (Belton et al., 2014), based on the existent reciprocal relationship observed in the literature between motor competence and PA (Figure 1.2) (Robinson et al., 2015; Stodden et al., 2008).

Fundamental movement skills (FMS), including jumping, running, skipping (locomotor), catching, kicking, striking, throwing (object control) and balancing, are the foundation for an active lifestyle (Gallahue & Ozmun, 2006; Lubans et al., 2012). Children have the developmental potential to master most FMS by six years of age (Gallahue et al., 2012), while other research has revealed that many children demonstrate mature patterns of motor development by the age of ten (Ulrich 2000).

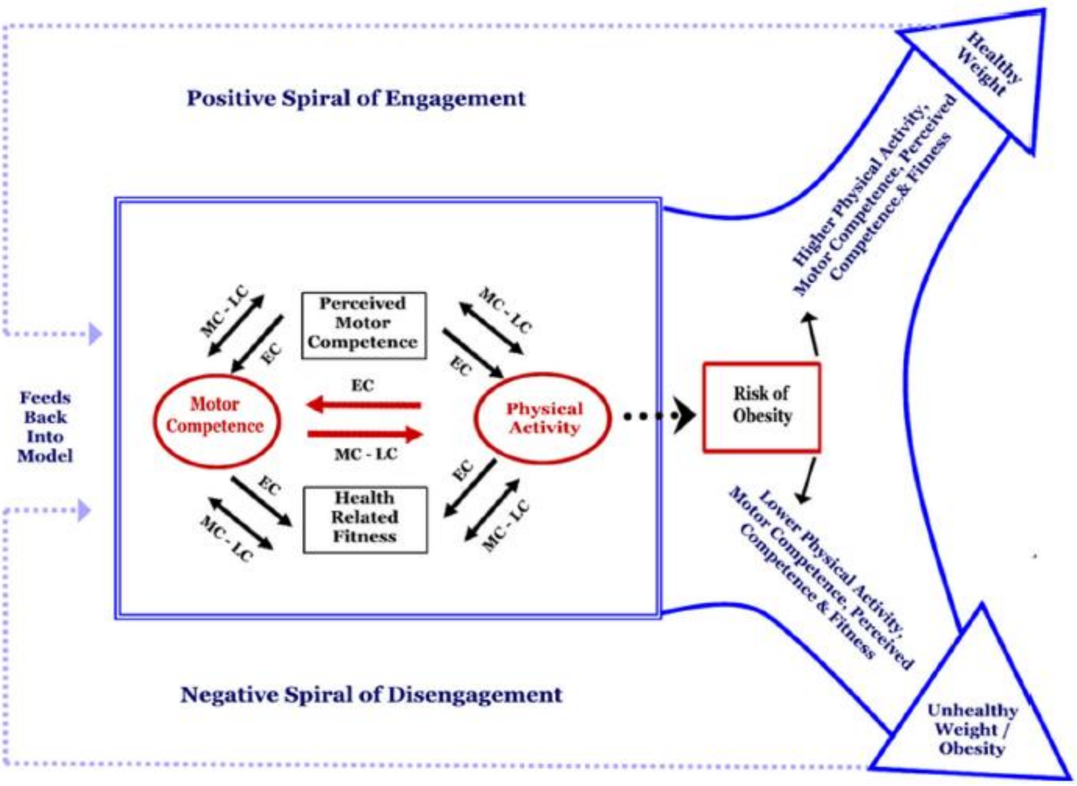

Figure 1.2: Developmental trajectory model of motor competence and physical activity (Stodden et al., 2008, p.294).

[*EC* = early childhood; *MC* = middle childhood; *LC* = late childhood]

Furthermore, FMS are one of the few modifiable risk factors for the prevention of poor health outcomes (Bremer & Cairney, 2016).

Considering the developmental potential of children, it would seem logical to suggest that these basic movement skills should already be mastered by Irish adolescents aged between 12 to 16 years old. Research, however, suggests that the current trends indicate that children and youth are insufficiently skilled, and have not achieved a level of FMS proficiency, that may be expected of their age (Belton et al., 2014; Booth et al., 1999; Foulkes et al., 2017; Hardy, Barnett, Espinel, & Okely, 2013; Hardy, King, Farrell, Macniven, & Howlett, 2010; Mitchell et al., 2013;

O'Brien, Belton, & Issartel, 2016). Crucially in Ireland, although there is a noticeable absence of data in relation to adolescent FMS proficiency, recent studies conducted with Irish primary and secondary school children have observed consistently low levels of FMS proficiency (Bolger et al., 2019; Issartel et al., 2017; Kelly, O'Connor, Harrison, & Ní Chéilleachair, 2019; Lester et al., 2017; McGrane, Belton, Fairclough, Powell, & Issartel, 2018; O'Brien et al., 2016; O'Brien, Duncan, Farmer, & Lester, 2018).

Evidence would suggest a need to improve FMS development, among children and adolescents, to optimise proficiency in these basic FMS prior to sport specific engagement. There is now strong cross-sectional and longitudinal evidence that identify FMS as a primary underlying mechanism that promote positive engagement in PA (Barnett, Morgan, van Beurden, Ball, & Lubans, 2011; Castelli & Valley, 2007; Fisher et al., 2005; Lima et al., 2017; Lloyd, Saunders, Bremer, & Tremblay, 2014; Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Robinson et al., 2015; Stodden et al., 2008; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). For example, longitudinal data has shown that mastery of FMS is associated with higher levels of PA in both children and adolescents (Cliff, Okely, Smith, & McKeen, 2009; Lloyd et al., 2014; Lubans et al., 2010). Conversely, if these FMS are not mastered, a knock on effect on PA levels may be observed, albeit evidence suggests that proficiency in a range of FMS may serve as a protective factor against this trend (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Lopes, Rodrigues, Maia, & Malina, 2011; Lubans et al., 2012).

A lack of proficiency in movement skills may be compounded by other intrinsic risk factors such as muscle asymmetry, core stability deficiencies, and postural defects (Morton, Barton, Rice, & Morrissey, 2014). This domain of movement is known as functional movement, defined as the ability to move the body with proper muscle and joint function (Coker, 2018), and is an important consideration for motor development, as it relates to an individual's mobility and quality of life (Edelson, Mathias, Fulgoni, & Karagounis, 2016). Functional movement is often measured by the globally established FMS™ (Cook, Burton, Fields, & Kiesel, 1998; Cook, Burton, & Hoogenboom, 2006b), a pre-participation evaluation tool that comprises a series of seven movements designed to simultaneously assess multiple domains of function including range of motion, stability, balance and the overall quality of movement patterns (Letafatkar, Hadadnezhad, Shojaedin, & Mohamadi, 2014; O'Connor, Deuster, Davis, Pappas, & Knapik, 2011; Wright et al., 2016).

The ability to execute different movements with correct technique should enable more effective force transmission within dynamic tasks, aid postural stability and body alignment within open skilled activities (Lloyd et al., 2015). Duncan and Stanley (2012) proposed that children with functional limitations may not develop their FMS to the same level of competency, as those without functional limitations. It stands to reason, therefore, that dysfunctional movements could impede motor development and performance in the adolescent population (Coker, 2018). International research, including most recent Irish data, has consistently highlighted deficits in functional movement patterns in adolescent populations (Abraham, Sannasi, and Nair 2015; Anderson, Neumann, and Huxel Bliven 2015; Lester et al.

2017; O’Brien et al. 2018; Paszkewicz, McCarty, and van Lunen 2013; Portas et al. 2016).

It is essential that motor competence is assessed and monitored into adolescence, to ensure the transition to more advanced movement skills and patterns are achieved. Indeed, opportunities to be physically active must be provided for FMS to be developed to a proficient level, however, it must be acknowledged that technological advances and safety concerns, particularly among children, have led to sedentary lifestyle behaviours becoming more commonplace (Kelly et al., 2019). To put this into context, high numbers of children and young people are failing to meet the sedentary screen time guideline (i.e., not more than 120 minutes/day), for example, only 52% of adolescents in first year of secondary school in Ireland self-reported to have met this guideline (Woods et al., 2018).

Schools are a favourable setting for interventions aimed at improving adolescent motor competence as they reach a majority of potential participants, and it is also well-known that adolescents spend a large portion of their waking hours in the school setting (Hankonen et al., 2016). The literature widely acknowledges that there is strong rationale for school-based programmes aimed at increasing FMS competence (Kalaja, Jaakkola, Liukkonen, & Digelidis, 2012; Lubans et al., 2012; McGrane et al., 2018; van Beurden et al., 2003), and more recently functional movement (Coker, 2018), particularly those delivered by qualified PE teachers, including the provision of professional learning opportunities (Cohen, Morgan, Plotnikoff, Barnett, & Lubans, 2015; Mitchell et al., 2013; Morgan et al., 2013).

Interestingly, the NPAP refers explicitly to quality physical education (QPE) as a means to assist children and young people in mastering FMS that enable them to engage more enjoyably in a wide variety of physical activities and sports (Healthy Ireland, 2016a). At Irish primary school level, 1 hour per week of PE is mandatory, and 2 hours per week is recommended for pupils at Irish secondary school level (European Commission & World Health Organization, 2016). It would seem reasonable to suggest that the school-based PE climate would be a suitable intervention setting.

There may, however, be an inherent need to transcend the PE environment towards more whole-school approaches, as only 23% of secondary school students meet the recommended PE guidelines of 120 minutes per week in school (Woods et al., 2018; World Health Organization, 2018a). It is, therefore, essential in the future design, development, implementation and evaluation of school-based interventions, to 1) understand and adapt the effective components from established interventions, and; 2) to consider the contextual factors associated with implementation, as an approach to help combat the identified national and global health problems.

1.2.2 Significance of the Study

This PhD research study is a unique intervention trial describing the design, development, implementation and evaluation of Project FLAME, a multi-component, school-based motor competence intervention for adolescent youth in Ireland. By using the established personnel and resources in the school setting, combined with effective evidence-based intervention strategies, this feasible and cost efficient programme is the first of its kind in an Irish population. Project FLAME simultaneously targets the improvement of adolescents' FMS and functional movement, as a means to counteract the steep decline in adolescent PA participation (Nader et al., 2008).

Project FLAME was initiated in March 2016, under the premise that understanding both FMS and functional movement as two elements within a continuum, could be seen a more rounded approach to motor development by reflecting more accurately the skills and movements inherent in a wider range of sports, and games in which adolescents participate (Coker, 2018; Lester et al., 2017). It is important to acknowledge, however, that there is a dearth of data and literature in relation to adolescent FMS, and in particular, functional movement, both in Ireland and worldwide. This study addresses these deficits by providing contextual information, as well as comparative reference data with international studies, for similar gender and age-related cohorts among 12 to 16 year old Irish youth.

The first phase of this study was cross-sectional in nature, and therefore used a descriptive research design, while the second phase of the study was based on an experimental research design (i.e., pre- and post-intervention data collection time points), specifically a non-randomized controlled trial. A positivist approach (i.e., research paradigm) was used as a conceptual framework for the study, such was the predominant quantitative nature of the research. Project FLAME was developed around a series of core theoretical constructs including elements of dynamical systems theory (DST), a mastery motivation (MM) instructional climate and the developmental model of MC. In brief, DST emphasises that it is the interaction between the person, the environment, and the task that changes how our movements are developed and acquired (Newell, 1986; Sigmundsson, Trana, Polman, & Haga, 2017). A MM climate enhances the intrinsic motivation and motor skill performance in children, and leads to the teacher adopting a more student-centred instructional approach (Bandeira, de Souza, Zanella, & Valentini, 2017; Martin, Rudisill, & Hastie, 2009; Ntoumanis & Biddle, 1999; Rudisill, Wall, Parish, St. Onge, & Goodway, 2003). Finally, at the heart of the developmental model of MC is a reciprocal and developmentally dynamic relationship between MC and PA participation in children and youth (Stodden et al., 2008). Essentially, the development of MC is a primary underlying mechanism that promotes engagement in PA (Robinson et al., 2015; Stodden et al., 2008). The Project FLAME intervention primarily focused on the proposed developmental model pathway between actual MC and PA, as mediated by perceived MC.

The Project FLAME intervention comprised of four major components, specifically the i) specialist PE teacher component, ii) kinaesthetic classroom component, iii) student component and iv) digital literacy component. The reported study design offers a feasible, targeted whole-school approach to increasing motor competence, and by incorporating a number of novel strategies, the findings from the study may have important implications for the future teaching and learning of PE at post-primary (secondary) school level. Furthermore, this research may, in time, prove significant from an individual, local and national perspective; providing each individual with the motor competence levels to enjoy health-enhancing PA for life, assisting undergraduate pre-service teacher training programmes in universities (along with in-service professional development), and supporting national coaching and government bodies in the development of strategies and policies to improve the overall health and wellbeing of young people, thereby reducing the current and future economic burden of both physical inactivity and obesity.

1.3 Aim and Objectives of the Study

Aim of the Research:

To design, develop, implement and evaluate the efficacy of Project FLAME: A multi-component, school-based, motor competence intervention for adolescent youth in Ireland.

Objectives:

To collect cross-sectional data on FMS, functional movement and perceived motor competence of 12–16 year old Irish adolescent youth.

To investigate gender and age-related differences in FMS and functional movement among a mixed-gender cohort of post-primary Irish adolescents.

To analyse movement skills (FMS) and patterns (functional movement) at a behavioural component level.

To design, develop and implement a multi-component, school-based motor competence intervention in two Irish post-primary schools over a 13-week period and evaluate its effectiveness on adolescents FMS and functional movement.

To assess changes from pre- to post-test in FMS and functional movement of the intervention group receiving Project FLAME, and to make comparisons with a control group.

1.4 Research Questions

1. What are the FMS and functional movement proficiency levels of 12–16 year old Irish adolescent youth?

2. Are there any identifiable gender and age-related differences in FMS and functional movement among post-primary Irish adolescents?

3. Will the analysis of FMS and functional movement, at a behavioural component level, provide a more robust insight into adolescent motor competence?

4. What are the essential components required for designing, developing and implementing a school-based, motor competence intervention (as guided by the literature and baseline data measurements)?

5. Is it possible to increase levels of FMS and functional movement over time (pre- to post-test) in post-primary youth through the Project FLAME intervention?

1.5 Thesis Structure

Following this introduction, chapter 2 critically reviews the literature in the areas of physical literacy, fundamental movement skills and functional movement. Chapters 3 and 4 gather cross-sectional data on adolescent youth, differentiated by gender and grade (age) across the first three years (Junior Cycle) of post-primary (secondary school) education, specifically to inform the development of Project FLAME. Chapter 5 is a methodological study looking at the design, development and implementation of Project FLAME, while chapter 6 assesses the efficacy of the intervention, specifically in terms of improving FMS and functional movement in adolescents.

Chapter 2: Literature Review. The second chapter summarises, synthesises and discusses the literature in the areas of physical literacy, FMS and functional movement, providing a comprehensive overview of the research in these areas to date.

Chapter 3: Do Irish adolescents have adequate functional movement skill and confidence? The purpose of this third chapter was to gather cross-sectional data on Irish adolescent youth, differentiated by gender, specifically in order to inform the development of a school-based, motor competence intervention.

Chapter 4: The age-related association of movement in Irish adolescent youth. The purpose of this fourth chapter was to gather cross-sectional data on Irish adolescent youth, specifically the prevalence of movement skills and patterns, in order to generate an overall perspective of movement within the first three years (Junior Cycle) of post-primary (secondary school) education.

Chapter 5: Rationale and study protocol for the Project FLAME non-randomized controlled trial: A multi-component, school-based, motor competence intervention for adolescent youth. The purpose of this fifth chapter was to describe the rationale and study protocol design used in the development and implementation of Project FLAME. Chapter 5 provides a detailed descriptive account of the intervention components.

Chapter 6: A school-based intervention to improve functional movement and fundamental movement skills in adolescent youth: Evaluating the effectiveness of Project FLAME. This chapter assesses the efficacy of the Project FLAME intervention in terms of improving adolescents FMS and functional movement over a 13-week period, when compared to a control condition. Data for this chapter was collected at 2 time points: pre-intervention (October/November 2017) and post-intervention (March 2018).

Chapter 7: Conclusions and Future Directions of Project FLAME. This chapter provides an overview of the thesis. It presents various strengths and limitations of the thesis. It also provides recommendations for further research and the future directions of Project FLAME as a whole.

1.6 Definition of Terms

fine motor skills: Fine motor skills generally involve movements predominately produced by the smaller muscles or muscle groups of the body (Payne & Isaacs, 2017). Fine motor skills refer to small object-handling activities that emphasise motor control, precision and accuracy of movement (Kalaja et al., 2012). Tying one's shoelaces, colouring, sewing and cutting with scissors are all examples of fine motor skills (Gallahue & Cleland Donnelly, 2003).

functional asymmetries: Functional asymmetries are defined as side-to-side differences in kinetics and kinematics during performance of otherwise symmetric tasks. Measurable levels of functional asymmetries have been found to be commonplace in healthy populations (Overmoyer & Reiser II, 2013).

functional movement: Functional movement is defined as the ability to move the body with proper muscle and joint function (Coker, 2018).

functional movement screen: The Functional Movement Screen (FMS™) (Cook et al., 1998; Cook, Burton, & Hoogenboom, 2006a; Cook et al., 2006b) is a pre-participation evaluation instrument that comprises a series of seven movements designed to assess multiple domains of function, and the quality of fundamental movement patterns (Letafatkar et al., 2014; O'Connor et al., 2011).

fundamental movement skills: Fundamental movement skills (FMS) are the basic observable building blocks or precursor patterns of the more specialised, complex movement skills required to successfully participate in organised and non-organised games, sports and recreational activities (Clark & Metcalfe, 2002; Hands, 2012). Examples exhibited during sport, exercise and PA include jumping, running, skipping (locomotor), catching, kicking, striking, throwing (object control), balancing, twisting and dodging (stability) (Department of Education Victoria, 1996; Gallahue et al., 2012).

gross motor skills: Gross motor skills are defined as motor skills that involve the large, force-producing muscles of the trunk, arms, and legs (Clark, 1994; Logan, Robinson, Rudisill, Wadsworth, & Morera, 2014). Throwing, catching, kicking, trapping, striking, volleying, bouncing, rolling, and punting are examples of gross motor skills (Kalaja et al., 2012).

intention-to-treat: In the context of statistical analysis, the intention-to-treat approach to loss to follow up is to make the 'worst case' assumption that due to non-compliance the intervention treatment has not been experienced, and to carry forward the baseline value, thereby assuming no change in cases.

interrater reliability: Interrater reliability shows that multiple raters scoring the same test (i.e., single trial) can report consistent results (Onate et al., 2012; Smith, Chimera, Wright, & Warren, 2013; Stobierski, Fayson, Minthorn, Valovich McLeod, & Welch, 2015; Teyhen et al., 2012).

intrarater reliability: Intrarater reliability shows that a single rater can provide consistent scoring results over repeated administrations (i.e., multiple trials) of a test (Stobierski et al., 2015).

ipsative assessment: Ipsative assessment is assessment against an individual's previous performance.

locomotor skills: In the context of FMS, locomotor (or locomotion) skills involve movement of the body from one point to another in a horizontal or vertical dimension (Gallahue & Cleland Donnelly, 2003; Kalaja et al., 2012). Moving the body through space during activities such as walking, running, jumping, galloping, skipping, hopping, sliding, leaping, and climbing are representative examples of locomotor skills (Bardid et al., 2016; Gallahue & Cleland Donnelly, 2003; Haywood & Getchell, 2019).

mastery: In the context of FMS, mastery involves displaying correct performance of all components of a skill, typically across two trials (Booth, Denney-Wilson, Okely, & Hardy, 2005; O'Brien et al., 2016; van Beurden, Barnett, & Dietrich, 2002).

mobility: Mobility refers to the combination of muscle flexibility, joint range of motion and a body segment's freedom of movement (Cook, Burton, & Fields, 2012).

motor competence: Motor competence (MC) is the ability to execute a wide and diverse range of motor tasks or actions in a skilful manner, which includes the movement quality, coordination of both gross and fine motor skills/activities, and control underlying a particular motor outcome (Burton & Miller, 1998; Gabbard, 2015; Gallahue et al., 2012; Haga, 2008).

motor development: Motor development can be defined as the process by which an individual progresses from simple movements to complex motor skills (Haywood & Getchell, 2014). Motor development, therefore, refers to the continuous, age-related process of change in movement, as well as the interacting constraints (or factors) in the individual, environment, and task that drive these changes (Haywood & Getchell, 2019).

object control skills: In the context of FMS, object control (or manipulation or ball) skills involve manipulation (i.e., reception and/or propulsion) of an object, such as a ball, with either the hand or foot (Gallahue et al., 2012). This includes transporting, intercepting, or projecting objects such as throwing, catching, dribbling, kicking, and striking (Goodway & Robinson, 2015; Logan, Kipling Webster, Getchell, Pfeiffer, & Robinson, 2015; Logan, Robinson, Wilson, & Lucas, 2012).

peak height velocity: Peak height velocity (PHV) reflects the age at which maximum rate of growth occurs during the adolescent growth spurt and is often used as a reference landmark to reflect the occurrence of other body dimension velocities or measures of physical performance (Lloyd et al., 2015; Malina, Bouchard, & Bar-Or, 2004; Mirwald, Baxter-Jones, Bailey, & Beunen, 2002).

physical activity: Physical activity (PA) is defined as any bodily movement, produced by skeletal muscles, that requires or results in energy expenditure. This includes activities undertaken while working, playing, carrying out household chores, travelling, and engaging in recreational pursuits (World Health Organization, 2018c).

physical education: Physical education (PE) is the planned, progressive learning that takes place in the school curriculum timetabled time and which is delivered to all students. This involves both 'learning to move' (i.e., becoming more physically competent) and 'moving to learn' (e.g., learning through movement, a range of skills and understandings beyond physical activity, such as co-operating with others) (afPE, 2015).

physical literacy: Physical literacy (PL) can be described as the motivation, confidence, physical competence, knowledge, and understanding to maintain PA throughout the life course (Whitehead, 2010).

process-oriented assessments: Process-oriented assessments evaluate how a movement is performed (i.e., technique used) based on the demonstration of behavioural criteria, allowing researchers to identify specific aspects of movement for each child that need to be improved upon (Logan, Barnett, Goodway, & Stodden, 2017; Logan et al., 2012).

product-oriented assessments: Product-oriented assessments evaluate the outcome of movement, typically identified as a quantitative score (e.g., speed, distance or number of successful attempts) (Logan et al., 2017).

reliability: Reliability refers to the consistency of scores of a particular instrument. Reliability is, therefore, a determination of whether two administrations of an instrument produce a similar result (Morgan, Gliner, & Harmon, 2001; Thomas, Nelson, & Silverman, 2011).

stability: Stability is the ability to maintain posture and/or control motion in a static or dynamic condition (Cook et al., 2012).

validity: Validity is a determination of the extent to which an instrument measures what we think it's supposed to be measuring (Thomas et al., 2011). Validity is concerned with establishing evidence for the use of a particular instrument in a particular setting with a particular population (Morgan et al., 2001).

1.7 List of Abbreviations

AfL = assessment for learning

afPE = Association for Physical Education

ANOVA = analysis of variance

ASLR = active straight leg raise

BMI = body mass index

CAPL = Canadian Assessment of Physical Literacy

CDC = Centers for Disease Control and Prevention

CI = collective intelligence

CI = confidence interval

CIT = Cork Institute of Technology

CPD = continuing professional development

CRF = cardio-respiratory fitness

CS4L = Canadian Sport for Life

CSPPA = Children's Sport Participation and Physical Activity Study

CST = Component Stage Theory

DEIS = Delivering Equality of Opportunity in Schools

DST = dynamical systems theory

EC = early childhood

FLAME = Fundamental and Functional Literacy for Activity and Movement Efficiency

FMS = fundamental movement skills

FMS™ = Functional Movement Screen™

FST = functional strength training

GMQ = gross motor quotient

GSGA = Get Skilled: Get Active

HALO = Healthy Active Living and Obesity Research Group

HBSC = Health Behaviour in School-aged Children

ICC = intraclass correlation coefficient

IPLA = International Physical Literacy Association

IT = information technology

ITT = intention-to-treat

JCPA = Junior Cycle Profile of Achievement

KTK = Körperkoordinationstest für Kinder

LC = late childhood

LPA = light physical activity

LTAD = Long-Term Athlete Development

M = mean

MC = middle childhood

MC = motor competence

MIGI = Move It Groove It

MM = mastery motivation

MMA = mixed martial arts

MNM = mastery and near mastery

MQ = motor quotient

MRC = medical research council

MVPA = moderate-to-vigorous physical activity

NASPE = National Association of Sport and Physical Education

NCCA = National Council for Curriculum and Assessment

NCD = noncommunicable disease

NPAP = National Physical Activity Plan

PA = physical activity

PDST = Professional Development Service for Teachers

PE = physical education

PHE = Physical and Health Education Canada

PHE = Public Health England

PHV = peak height velocity

PI = principal investigator

PL = physical literacy

PLAY = Physical Literacy Assessment for Youth

PMC = perceived motor competence

PSPP = physical self-perception profile

QPE = quality physical education

QR = quick response

RCT = randomized controlled trial

ROC = receiver operating characteristic

ROM = range of motion

SD = standard deviation

SHAPE = Society of Health and Physical Educators America

SLAR = Subject Learning and Assessment Review

SPSS = Statistical Package for Social Sciences

SREC = Social Research Ethics Committee

TGMD = test of gross motor development

TGMD-2 = test of gross motor development-2

TGMD-3 = test of gross motor development-3

TREND = Transparent Reporting of Evaluations with Non-randomized Designs

TSPU = trunk stability push-up

TST = traditional strength training

UCC = University College Cork

UNESCO = United Nations Educational, Scientific and Cultural Organization

USA = United States of America

VLE = virtual learning environment

VPA = vigorous physical activity

Y-PATH = Youth-Physical Activity Towards Health

WHO = World Health Organization

1.8 Schematic Overview

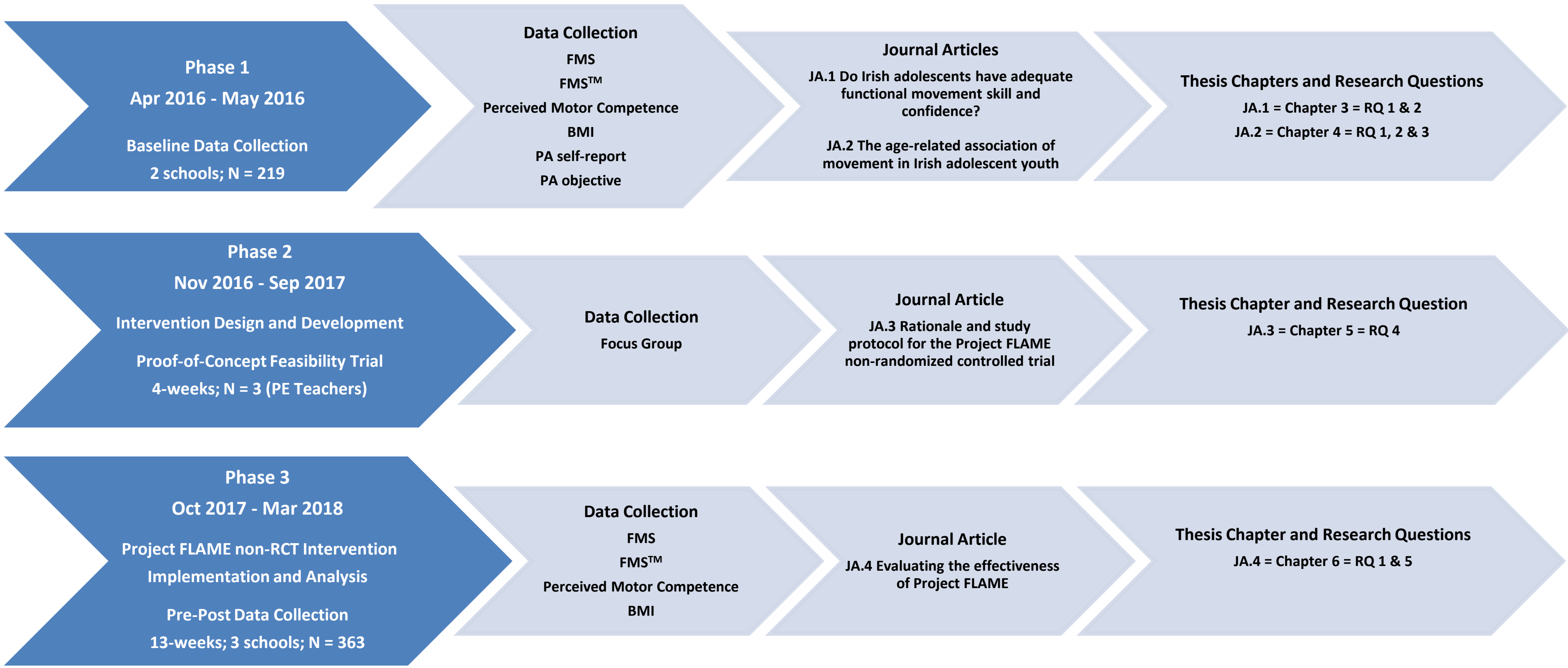

Figure 1.1: Schematic Overview of Project FLAME (Fundamental and Functional Literacy for Activity and Movement Efficiency)

[*BMI* = body mass index; *FMS* = fundamental movement skills; *FMS*™ = Functional Movement Screen; *JA.1* = journal article 1 etc.; *PA* = physical activity; *RCT* = randomized controlled trial; *RQ 1* = research question 1 etc.]

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Chapter 2

Literature Review

2.1 Physical Literacy

2.1.1 Definitions of Physical Literacy

2.1.1.1 The Whitehead Evolution of Physical Literacy

Physical literacy (PL) can be described as the motivation, confidence, physical competence, knowledge, and understanding to maintain physical activity (PA) throughout the life course (Whitehead, 2010). PL is, therefore, a multi-dimensional concept that places importance on the holistic development of an individual's physical potential (Cairney, Dudley, Kwan, Bulten, & Kriellaars, 2019; Whitehead, 2010, 2013a). The term PL was used as early as 1930 in educational journals in the United States and Britain as a metaphor that invited comparison with language literacy (Jurbala, 2015). Margaret Whitehead has provided much of the philosophical foundation for our understanding of PL, and her work has been instrumental in the refinement and improvement of the PL definition, since the author first began elaborating on these ideologies, beginning in the early 1990s (Whitehead, 2001, 2007). Although the term has been in use in the United Kingdom since at least the 1980s, it is Whitehead who has been largely responsible for giving the concept its current form (Jurbala, 2015).

2.1.1.2 Alternative Definitions and Interpretations of Physical Literacy

The diversity in global PL definitions have generated a level of inconsistency and conflict within the literature, hindering research on the topic (Cairney, Clark, Dudley, & Kriellaars, 2019; Dudley, Cairney, Wainwright, Kriellaars, & Mitchell, 2017; Jurbala, 2015; Shearer et al., 2018; Tremblay & Lloyd, 2010). It is possible that the use of a metaphorical interpretation of PL, rather than a theoretical foundation have enabled various explanations and re-definitions of the term (Jurbala, 2015). Although international differences in the interpretation and operationalisation of PL are expected, indeed needed, for the creation of meaningful and cultural relevance (Shearer et al., 2018), PL has been limited by pre-existing and sometimes biased interpretations of the construct (Dudley et al., 2017). PL is now well-established as having competing definitions (Higgs, 2010; Whitehead, 2010), and debate among practitioners in terms of how best to employ the term in practice (Jurbala, 2015).

According to Dudley (2015, p.238), "*PL should be viewed as an umbrella concept that captures the knowledge, skills, understandings, and values related to taking responsibility for purposeful PA and human movement across the life course, regardless of physical or psychological constraint*" (Dudley, 2015; Dudley et al., 2017). The reference to Dudley's (2015) human movement concept for PL is interesting and comparable, as Mandigo et al. (2009) have previously stated that PL is the ability to move with competence and confidence in a wide variety of physical activities in multiple environments that benefit the healthy development of the whole person.

Physical and Health Education (PHE) Canada adopt the Whitehead (2016) approach in defining PL as "*the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities*" (Whitehead, 2016), and interestingly, the International Physical Literacy Association (IPLA) also adopt Whitehead's (2016) definition in their description of lifelong PL (IPLA, 2017; Whitehead, 2016). Considering that both of these national and international associations advocate for individual PL characteristics (e.g., motivation, knowledge, physical competence) and share commonality in this regard, the IPLA definition specifically emphasises engagement in PA for life (Longmuir & Tremblay, 2016). This consideration from the IPLA is significant, as Whitehead (Whitehead, 2001, 2010) consistently argues that PL represents a lifelong journey (Shearer et al., 2018).

A recent systematic review of the definitions of PL conducted by Edwards, Bryant, Keegan, Morgan, and Jones (2017), found that 'throughout the lifespan' and the overarching focus on 'lifetime PA' were core categories in the empirical definitions and commonalities of PL (Corbin, 2016; Shearer et al., 2018). Although the Canadian consensus statement (Canadian Sport for Life (CS4L), 2015) went some way toward unifying an acceptable approach to PL, research would suggest that there is a marked difference between endorsing a definition, and appropriately operationalising an identified definition (Edwards et al., 2017; Shearer et al., 2018).

The inclusion of PL in sport, recreation, and education policy have been undeniably important in popularising the PL concept in practice (Jurbala, 2015). PL provides a term that facilitates collective efforts among a variety of institutions, and indeed countries, to respond to the declining rates of lifelong PA participation and the consequences of physically inactive and sedentary lifestyles (Aspen Institute, 2015). Tompsett et al. (2014) highlight the associated characteristics of a physically literate individual, with their work specifying competent movement forms within different environments and contexts, and the ability to utilise personal movement potential, motivation and confidence to participate in lifelong habitual exercise (Whitehead, 2001, 2005, 2007). In light of all of these conflicting and comparable global PL definitions, it is reasonable to state based on existing research that individuals with more advanced PL are more able to participate in and enjoy lifelong PA, as well as being less likely to suffer acute exercise-related injury and inactivity-related illness, setting up a virtuous cycle that supports enhanced quality of life (Jurbala, 2015).

2.1.2 Measurement/Assessment of Physical Literacy

2.1.2.1 The Need to Measure Physical Literacy

Assertions that PL can be a rallying point for renewed effort to increase PA, and that early attainment of PL is essential for later success in sport, along with the inclusion of PL in PE curricula, have led to both a demand and interest in research-informed assessment protocol for PL (Jurbala, 2015). Specifically, Tremblay and Lloyd (2010) argued that measurement is the missing piece related to PL. A need that emerges in the discussion of assessing PL is the argument that quality assessment tools are needed in practice to heighten the embodied experience and knowledge of students (Lundvall, 2015). It is important to reiterate that Whitehead emphasizes that PL is a journey, not something that occurs at one point in time (Tremblay & Longmuir, 2017). The multiple characteristics associated with PL make it clear that it is a multi-dimensional concept for assessment (Corbin, 2016; Tremblay & Longmuir, 2017). In planning future research and practice, the importance of identifying and defining specific characteristics of PL will be needed to develop appropriate assessment procedures for each construct or variable (as opposed to attempting to develop a general test) (Corbin, 2016).

2.1.2.2 Issues with Measuring Physical Literacy

While many practitioners, policy makers and stakeholders currently advocate for PL programmes, interventions, and the necessity of empirical support for such approaches (Jurbala, 2015), the varying definitions of PL adopted in the field differ (Edwards et al., 2017; Keegan, Keegan, Daley, Ordway, & Edwards, 2013), thus causing disparities on how to best operationalise and measure/assess the concept (Edwards et al., 2018). Current research adopts diverse, and often incompatible methodologies in measuring and/or assessing PL (Edwards et al., 2018). This uncertainty has occurred as a result of the development of PL assessment protocols, arising from different definitions that proceed to use different practical approaches for measurement (Jurbala, 2015; Kriellaars, 2013; Tremblay & Lloyd, 2010). The demand for creating practical PL tests has also led to a concept known as 'reductionist reverse engineering', where many researchers have discarded much of the holism associated with the Whitehead PL definition (Jurbala, 2015). The PL concept has, therefore, been interpreted in ways that facilitate instrumental use, but diverge from original holistic conceptions. Increasingly, the term is used to describe a measurable outcome of a developmental process (Jurbala, 2015).

A criticism of the assessment approaches is that these tools or batteries mainly focus on physical and motor capability, over and above other psychological components of PL (Edwards et al., 2018). Current PL assessments are often quantified by how well a child performs fundamental movement skills (FMS) (i.e., catching, jumping, kicking, throwing etc.) (Tompsett et al., 2014) or exhibits basic motor competence (MC). It may be naive, as Pot and van Hilvoorde (2013) demonstrate, that learning the building blocks of movement, regardless of being referred to as PL or FMS, will lead to sport participation (Lundvall, 2015). According to Edwards et al., (2018), quantitative measures/assessments more readily facilitate judgments of reliability, validity, and replicability; however, they are less aligned with PL's holistic philosophy, as defined by Whitehead. Qualitative methods have more potential to measure/assess the affective and cognitive domains than the physical domain of PL, albeit no currently available qualitative technique can adequately measure/assess all PL domains, particularly in a way that reflects the integrated non-linear nature of the concept (Edwards et al., 2018). The tension, therefore, appears to be between the desire to develop consistent, reliable, and valid measures of PL, in comparison to the viewpoint that PL is inherently complex and dynamic, and thus not readily measured (Edwards et al., 2018).

2.1.2.3 Different types of Physical Literacy Assessment

While it is encouraging that the PL agenda is advancing on a practical level, the degree to which these measurement/assessment attempts capture the multi-faceted and relatively unique characteristics of PL remains questionable (Dudley, 2015; Edwards et al., 2018). Assessments such as Physical and Health Education Canada's (PHE Canada) 'Passport for Life' (Lodewyk & Mandigo, 2017; PHE Canada, 2014) facilitate multi-year tracking of student progress, offering the possibility of ipsative comparison, and supporting the idea of the lifetime PL journey (Jurbala, 2015; Whitehead, 2010). The Physical Literacy Assessment for Youth (PLAY) tool (Kriellaars, 2013) is another example of an assessment designed to assess PL, but this is limited to a set of ground-based locomotor, object control, balance and stability tests, combined with questions to assess understanding (Jurbala, 2015). Most recent research, however, highlights that a combination of methods may be required to better characterize overall PL progress (Edwards et al., 2018).

Although several instruments have been created to measure PL (Robinson & Randall, 2017), only one measure/assessment to date has attempted to collectively measure/assess the three domains of PL (physical, affective, and cognitive) (Edwards et al., 2018). The Canadian Assessment of Physical Literacy (CAPL) (HALO, 2013), is a large field-based assessment tool that monitors PL among children 8-12 years of age (Lundvall, 2015), and the only assessment of children's PL that has undergone extensive peer-reviewed and published validation efforts, including assessments of feasibility, validity, and reliability (Francis et al., 2016; Longmuir, 2013; Longmuir et al., 2015, 2018). The CAPL attempts to identify the current and most favoured measurement approaches for each recognised component of PL, namely competence, confidence, motivation, and knowledge (Edwards et al., 2018).

The CAPL incorporates 25 measures within four interrelated core domains; 1) motivation and confidence, 2) physical competence, 3) knowledge and understanding, and 4) daily activity behaviour (Tremblay & Longmuir, 2017; Tremblay et al., 2018)**.** The CAPL scoring system was developed using a Delphi process with international experts in various fields representing the four domains (Francis et al., 2016). An overall PL score (out of 100), as well as individual domain scores, are calculated using the CAPL (Longmuir & Tremblay, 2016; Tremblay et al., 2018). The core point of this assessment tool is to follow the child's development through a process-oriented assessment protocol. The protocol evaluates achievement stages using a 4-point classification, specified as emerging / beginning, developing / progressing, acquired / achieving and/or accomplished competence / excelling (Lundvall, 2015). The ratings are based on progress on the journey toward becoming physically literate. CAPL is "*the first comprehensive protocol that can accurately and reliably assess a broad spectrum of skills and abilities that contribute to and characterize the PL level of the participant*" (HALO, 2013, p.6; Longmuir, 2013). The CAPL is specifically designed as a modular assessment that can be tailored to the learning objectives of the educational setting, enabling teachers to decide whether a comprehensive, multi-dimensional, or more targeted assessment is best suited to their learning objectives (Tremblay & Longmuir, 2017)**.**

The CAPL-2 (HALO, 2017) is the second version of this instrument, which has been validated across a sample of over 10,000 children (N = 10,034; 50.1% females (n = 5030); mean age: 10.1 ± 1.2 years), collected from 11 sites across Canada (Tremblay et al., 2018). The goal of the changes (i.e., a revised, shorter, and theoretically stronger version of the CAPL) (Gunnell, Longmuir, Barnes, Belanger, & Tremblay, 2018) was to ensure that the outcomes from this assessment accurately and reliably reflect a child's current level of PL. Essentially, Gunnell et al.,'s (2018) factor analyses found that the CAPL could be reduced to 14 indicators across the same four domains (Gunnell et al., 2018). This second version represents the culmination of the Healthy Active Living and Obesity (HALO) research group's efforts, with input from over 100 researchers and practitioners from the field of study (HALO, 2017). The CAPL (i.e., editions 1 and 2) continues to be one of the only PL assessments with peer-reviewed evidence protocol for validity and reliability

(Longmuir et al., 2018). Interestingly, a recent preliminary validity study by Blanchard, van Wyk, Ertel, Alpous, and Longmuir (2020) on 245 adolescents (52.7% female (n = 129); mean age: 13.7 ± 0.9 years) suggests that a modified version of the CAPL (CAPL 789) has sufficient validity and is feasible for assessing the different components (e.g., physical skills, knowledge, strength, etc.) of PL in adolescents from grades 7 to 9 (i.e., 12 - 16 years old). Additional research is required to establish the psychometric properties in the 12 to 16 age cohort, while future research is recommended to further evaluate these protocols among larger samples from regions across Canada, and further afield (Blanchard et al., 2020).

Although there are inherent benefits in the CAPL, a number of concerns have also been highlighted in the literature. The use of a general (i.e., aggregate) score, for example, by combining ratings on a number of different specific characteristics has the potential to misguide those who are being tested (Corbin, 2016). As well as that, the use of scores that combine similar but independent characteristics is of concern (Corbin, 2016). Motor skill and physical fitness are combined into a single physical competence score, alongside the combination scores of motivation and confidence, which make it difficult to interpret the data (Corbin, 2016). From an age-related perspective, the Aspen Institute (2015) specify that "*it is Canada's goal for every child to be physically literate by the age of twelve*" (Aspen Institute, 2015a). From a CAPL perspective, research is challenging the assumption that PL can be achieved by the age of twelve, and furthermore, whether literacy, as measured by snapshots up to the age of twelve years old is truly indicative of literacy over the life course (Corbin, 2016). Finally, the CAPL has been criticised for treating the core domains as distinctly separate variables, and providing a disproportionate focus in favour of the physical and MC areas (Edwards et al., 2018).

2.1.2.4 The Role of Schools/Teachers in Physical Literacy Assessment

Given the recent demand on schools to continually assess learners' progress, adopting quantitative measures/assessments may help teachers to track student progress, identify areas for development, and plan interventions tailored to each learner (Edwards et al., 2018; Longmuir, 2013). Contrary to this viewpoint, teachers engaging with the concept of PL should be reminded and assured that measuring/assessing PL quantitatively is not the quintessential component of the concept: i.e., the pedagogical processes that generate motivated, confident, and knowledgeable learners are imperative to engage children in PA throughout the life course (Edwards et al., 2018; Sprake & Walker, 2013). If practitioners use measures/assessments without consideration for pedagogy, they are likely to disengage children, thus contradicting the key purpose of the concept (Edwards et al., 2018; Whitehead, 2010). Whitehead (2007) emphasises that programming must also incorporate assessment for learning (AfL) by supporting students in adopting a critically reflective approach. Using assessment for learning strategies would provide a greater focus on formative, as opposed to summative assessment strategies, which is consistent with high-quality and meaningful physical education (PE) (Edwards et al., 2018; Department for Education and Skills, 2004).

2.1.3 Physical Literacy and Physical Education

2.1.3.1 Positioning Physical Literacy within Physical Education

PL is a concept that encompasses the mind and body in an integrated way to explain, promote, and help sustain human beings' fundamental function: movement (Chen, 2015). The term has gained momentum within PE objectives, because PL encompasses all the aspects of a physically educated person, with the additional benefits of providing a parallel language to other school subjects, a common purpose and strong rationale for the subject in schools (Chen, 2015; SHAPE America, 2013; Roetert & MacDonald, 2015).

From a practical standpoint, the concept of PL helps teachers to articulate meaningful content to learners, and the general public as to what PE is trying to accomplish (Roetert & MacDonald, 2015). The educational value of PL also positions PE on a more level playing field, with other subject areas such as health, mathematics, and music, which have adopted the term literacy (Roetert & MacDonald, 2015). In the United States, PL is now used as both an outcome and a justification in PE (SHAPE America, 2013; Tremblay & Lloyd, 2010), and through this educational standpoint, PL is gaining academic credibility through the subject of PE (Corbin, 2016). One of the arguments in favour of the use of the term PL is that it can provide a blueprint for programme development and assessments, or more specifically in an educational context, PL has the potential to provide a framework for teachers to use in developing curricula and lesson plans (Corbin, 2016; Roetert & MacDonald, 2015).

2.1.3.2 Physical Literacy as the goal of Physical Education

Internationally, PL is a recognised component of PE, for example in the United States, the goal and outcome of meaningful PE is "*to develop physically literate individuals who have the knowledge, skills and confidence to enjoy a lifetime of healthful PA*" (SHAPE America, 2013, p.1). The National Physical Activity Plan (NPAP) for Ireland has also identified that "*in schools, learning in PE helps children and young people develop the knowledge, skills and positive attitudes that support and enable them to lead physically active lifestyles*" (Healthy Ireland, 2016, p.17). The term 'physically educated' implies a finished product, an end state which cannot be built on in the future, while 'physically literate' connotes a level of development that can be extended, an ongoing process according to an individual's interests and capabilities, whereby progress is always possible (Roetert & MacDonald, 2015; Whitehead, 2013c). Roetert and Jefferies (2014) in reviewing evidence-informed definitions of PL, concluded that PE develops physical competence, so that all children can move efficiently, effectively, safely and understand what they are doing, while PL, as the goal of PE, serves as the target of instruction for teachers and contributes to a critical aspect to educating the whole child (Roetert & Jefferies, 2014; Roetert & MacDonald, 2015; Whitehead, 2013a).

As applied to PE, literacy might be interpreted as moving psychomotor learning objectives to the affective and cognitive domains (Roetert & MacDonald, 2015). Lounsbery & McKenzie (2015) expressed concern about the shift away from doing (SHAPE America, 2004) to knowing (SHAPE America, 2013) in PE, and the de-emphasis of the physical domain (Lounsbery & McKenzie, 2015). Nevertheless, many believe PL offers a new approach for school-based PE, a goal that can be articulated and defended with confidence to reveal the intrinsic value of PA (Roetert & MacDonald, 2015; Whitehead, 2013a). It is asserted that PL-based school programming "*is likely to be a richer and more real learning experience for secondary school aged pupils*" (Killingbeck, Bowler, Golding, & Sammon, 2007, p.20). Given the adoption of PL objectives in school curricula, it is critically important for physical educators to understand how to deliver meaningful PL-based programmes (Jurbala, 2015; Mandigo et al., 2009).

2.1.3.3 Actualizing Physical Literacy in Physical Education

Actualizing PL means implementing highly effective instructional strategies (Roetert & MacDonald, 2015)**.** These types of educational practices facilitate the development of movement competency, are inclusive of all students, and reduce the likelihood of disengagement in PE (SHAPE America, 2013). The Society of Health and Physical Educators (SHAPE) America asserted that PE "*develops the physically literate individual through deliberate practice of well-designed learning tasks that allow for skill acquisition in an instructional climate focused on mastery*" (SHAPE America, 2017, online). Children should experience tasks that inspire them to embody competence and interest (Chen, 2015). According to Edwards et al. (2018), when applying high-quality pedagogy for fostering PL, practitioners should also create a caring educational ethos (Fry & Gano-Overway, 2010), develop an empowering climate (Appleton, Ntoumanis, Quested, Viladrich, & Duda, 2016), and implement a motivational atmosphere (Keegan, Spray, Harwood, & Lavallee, 2010).

PL necessitates teaching a broad spectrum of movement activities to children and young people from multiple categories, while also not relying on a team sport model that appeals to only the highly skilled and competitive students (Roetert & MacDonald, 2015). The content of PL integration within PE should minimize opportunities for social comparisons among students, which are potentially embarrassing, by decreasing competition and focusing on individual effort and progress. This educational focus for PL through the subject of PE should also help move students toward independent participation in PA throughout the lifespan (Roetert & MacDonald, 2015). The NPAP for Ireland "*recognises the need for a co-ordinated approach to the development and provision of high quality physical education (QPE) and the effective delivery of PL programmes which are essential for children to have the skills and confidence for lifelong participation in sport and physical recreation*" (Healthy Ireland, 2016, p.18). The importance of meaningful movement activity types, already utilised in the PE curricula are highlighted as the main requirement for establishing PL (Keegan et al., 2013; Tompsett et al., 2014). FMS as a pillar, are considered an important ingredient within the physical competence domain of PL, and have generated a recent surge of attention among practitioners globally. This focus of attention towards FMS integration can be attributed to the well-established associations to lifelong participation in PA, health benefits and sporting success for children and youth (Cliff et al., 2012; Larsson & Quennerstedt, 2012; Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Tompsett et al., 2014).

2.1.3.4 Concluding Comments on Physical Literacy and Physical Education

An argument can be made for PL as the primary goal of PE, but it should be noted that PL (depending on how it is operationally defined) can be developed in many different ways (e.g., sport, recreation, family), and the concept is not, and should not be exclusive to PE (Corbin, 2016). Castelli, Barcelona, and Bryant (2015) noted that even within schools, a comprehensive approach, more than PE alone is necessary (Corbin, 2016). That said, "*the curricular aspirations for PL confront the challenge of entrenched culture*" (Jurbala, 2015, p.372), and help reinstate the accountability and educational values of PE (Lundvall, 2015). Penney et al. (2009), drawing on Bernstein's (1977) conceptualization of curriculum, argue for the inter-relationship between curriculum, assessment, and pedagogy as a fundamental dimension of quality PE (Edwards et al., 2018). Within PL, actual movement competencies should be analysed annually for the whole school population to assess which children have the required movement abilities to progress through PE, sport and recreational PA (Tompsett et al., 2014).

2.1.4 Motor Competence and Physical Literacy

2.1.4.1 The Movement Emphasis within the Physical Literacy Rationale

MC is the ability to execute a wide and diverse range of motor tasks or actions in a skilful manner, which includes the movement quality, coordination of both gross and fine motor skills/activities, and control underlying a particular motor outcome (Burton & Miller, 1998; Gabbard, 2015; Gallahue, Ozmun, & Goodway, 2012; Haga, 2008). MC is essentially a broad concept encompassing FMS (Gallahue et al., 2012), for example, which are discussed in detail later in this chapter. PL also accepts, and actively promotes movement skill development (Dudley et al., 2017; Jurbala, 2015). FMS, including locomotor, object control, balance, agility skills, and fundamental sport skills, are considered a critically important correlate of a child's motor abilities, and subsequent contribution to PL (Tompsett et al., 2014).

Developing FMS in children is considered an essential component of PL (Mitchell & Le Masurier, 2014). Interestingly, Murdoch and Whitehead (2013) place a special emphasis on the importance of MC for PL, especially in the acquisition of fundamental movement vocabulary (taught through demonstration, observation as well as practice), which is the foundation for more specific movement skills (Murdoch & Whitehead, 2013; Roetert & MacDonald, 2015). Some definitions of PL have focused solely on the physical and MC aspects, including motor development ("*the continuous, age-related process of change in movement as well as the interacting constraints (or factors) in the individual, environment, and task that drive these changes*" (Haywood & Getchell, 2019, p.5)) (Caput-Jogunica, Loncaric, & De Privitellio, 2009) and FMS (Almond, 2013), while the Aspen Institute (2015) have also emphasised motor development (Corbin, 2016).

The application of PL in Canada, the United States, the United Kingdom, and Australia have focused strongly on developing FMS among children and young people (Mitchell & Le Masurier, 2014). Countries have defined PL as applying FMS with confidence (Northern Ireland) (Delaney, Donnelly, News, & Haughey, 2008) in a range of multiple environments to benefit the development of the whole person (PHE Canada) (Francis, Johnson, Lloyd, Robinson, & Sheehan, 2011; Mandigo et al., 2009; Robinson & Randall, 2017), while according to SHAPE America, the country's national standards for PE, the physically literate individual should demonstrate competency in a variety of motor skills and movement patterns (SHAPE America, 2013). Tompsett et al. (2014) purports that physiological, psychological and behavioural development of children, alongside the improvement of PL and long term active lifestyles are attributed to FMS proficiency (Cliff et al., 2012; Ford et al., 2011; Hardy, Barnett, Espinel, & Okely, 2013; Larsson & Quennerstedt, 2012; Lubans et al., 2010).

2.1.4.2 The Environmental Provisions of Movement within Physical Literacy

Much explanation of PL in existing PE curricula and sport coaching pedagogy has focused on the need for the development of FMS, linked to the maturity and developmental readiness of the learner (Jurbala, 2015). Many programmes, including the recent 'Move Well, Move Often' resource for Irish primary schools (PDST, 2017), as well as Public Health England's (PHE) briefing on what works in schools and colleges to increase PA (Public Health England, 2015), explicitly state their focus on developing PL among children and adolescents through the lens of FMS (i.e., psychomotor domain) (Mitchell & Le Masurier, 2014). By developing FMS at an early age, children find the competence and confidence in movement, which are important ingredients for PL, and children are therefore more likely to find long-term and sustainable enjoyment in sport and PA (B. Mitchell & Le Masurier, 2014). Research has advocated that competent FMS execution, along with the additional emphasis on PA participation as a whole for the child can combat earlier dropout, specifically during crucial transition periods, such as the windows associated with the commencement of formal schooling (5–6 years old), primary to high school (12–13 years old) and school to higher education or the workforce (17–18 years onwards) (Hills, King, & Armstrong, 2007; Tompsett et al., 2014). While programmes identify childhood (5–12 years) as the appropriate ages for developing FMS, the Long-Term Athlete Development (LTAD) model (Balyi, Way, & Higgs, 2013) does indicate that adolescence could be a time for working with students who need remedial work on the FMS (Mitchell & Le Masurier, 2014).

Higgs, Balyi, Way, Cardinal, Norris, and Bluechardt (2008) asserted that to develop PL, children must learn FMS which sequence movements to meet intended outcomes relevant to the rules of diverse sport activities in four basic environments, on the 1) ground, 2) in water, 3) on snow and ice, and 4) in the air. As highlighted by Cairney et al. (2019), virtually all definitions of PL include the specification of being competent in movement skills as a core domain (Dudley et al., 2017; Edwards et al., 2018). Public health, sport, and education agencies should collaborate in the mobilization of knowledge to ensure that the development of MC enables the widest possible participation outcomes across the lifespan (Dudley et al., 2017). Importantly, as indicated above, MC must be applied across a range of contexts, including land, air and water (Cairney, Dudley, et al., 2019; Hastie & Wallhead, 2015; Whitehead, 2001). PL policy should also actively discourage the early specialization of sport/activity-specific skills in favour of exposing youth to movement skills that have the greatest capacity of transferability and cross-activity participation (Dudley et al., 2017).

According to Whitehead, "*motor development is the vital first step to becoming physically literate*" and it is important that "*support, guidance and encouragement for all young people is provided to enable them to develop the wide range of motile capacities*" (Whitehead, 2004, p.18). Motor development is, therefore, influenced by exposure to movement demands, adequate instruction, social and genetic factors (Keiner, Sander, Wirth, & Schmidtbleicher, 2013). Despite this motor domain emphasis through varying constructs (such as motor development, MC, and FMS), PL is acquired through far more than movement and sport skills alone, "*it is developed through a complex interplay between the individual, their peers and their community, society and world*" (Hayden-Davies, 2008, p.23).

2.1.4.3 Challenges to Motor Competence and FMS within Physical Literacy Research

As previously presented, it is acceptable in the literature that PL is an active proponent of movement skill development (Dudley et al., 2017). Almond (2013), however, identifies some problems through the consistent labelling of FMS and PL in the existing research (Dudley et al., 2017). The list of FMS (being limited to locomotor, object control, and stability) creates a problem because to some practitioners, and by default, policymakers, FMS can be taught in isolation (Dudley et al., 2017). It is important to note that in order to dispel the stigma attached exclusively to FMS and PL, the term MC was adopted from the PL literature (Dudley et al., 2017). This notion is supported by Whitehead (2010) and Dudley (2015), as the revised definition amendment has reframed the building block of FMS as a bank of motor competencies (MCs). PL policy needs to ensure that the promotion and development of MCs does not occur at the expense of wider lifelong PA pursuits and opportunities (Dudley et al., 2017).

PL is an instrument to understand all human movements, and understandably, placing a primary focus on movement and sport-specific skills alone is narrowing the scope of the concept to sporting contexts only (Larsson & Quennerstedt, 2012). Consequently, solely defining PL by FMS performance may be ignoring several characteristics of the concept (Tompsett et al., 2014). If the majority of programmes and organizations promoting PL focus exclusively on FMS, it is unlikely that researchers and practitioners will develop all of the associated PL competencies (i.e., knowledge, skills and attitudes) that develop physically literate individuals for engaging in lifelong PA (Mitchell & Le Masurier, 2014). The curriculum in PE as a taught subject, and PL, are susceptible to criticism due to their focus on developing sports skills, instead of encouraging holistic movement for all children (Graf et al., 2005; Tompsett et al., 2014). Cairney et al. (2019) also argue that the execution of motor performance on its own is insufficient for learning, if it is not experientially linked with positive emotional states (enjoyment), which leads to a desire to repeat the skill and use it to engage in other activities, such as sport (motivation), all within a particular social context or physical environment.

2.1.5 Conclusion

PL involves a continuum of learning, by enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society (Whitehead, 2013b). In Whitehead's work, PL is a lifelong process, a disposition that allows all individuals to pursue meaningful PA throughout their lives, regardless of physical endowment (Roetert & MacDonald, 2015; Whitehead, 2013c). The importance of PL has been acknowledged by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) to generate healthy, able, and active citizens as an outcome of high-quality PE (Edwards et al., 2018; UNESCO, 2015). With PL as a focus in PE, students will learn about numerous aspects of their embodiment and become competent in meaningful movement activities (Roetert & MacDonald, 2015).

PL is often positioned as the gateway to lifelong participation in PA (Balyi et al., 2013; Cairney, Dudley, et al., 2019; Cairney, Kiez, Roetert, & Kriellaars, 2019; Stevens-Smith, 2016), as healthy living and being physically active for life are the underlying messages and goals of PL (Mitchell & Le Masurier, 2014). PL calls for meaningful embodiment of all the aspects that are required by active participation in PA, including a sound mental model, with scientific knowledge, adequate motor skills relevant to the types of PA to be engaged, appropriate physical fitness levels enabling effective participation, and sustained motivation for continued exertion of effort (Chen, 2015). What is clear at present is that the concept of PL appears to be capable of providing a clearer framework for re-conceptualization and re-organization of policy for strategic stakeholders in health, sport, and education (Almond, 2013; Chen & Sun, 2015; Dudley et al., 2017). To achieve alignment between the definition, philosophy, and outcome measure/assessment, researchers working within PL should be explicit about the definition and philosophy they adopt (Edwards et al., 2018). Developing and maintaining PL will not only enhance an individual's quality of life, but it may promote healthy living practices to family, friends and associates (Ragoonaden, Cherkowski, & Berg, 2012; Tompsett et al., 2014; Whitehead, 2001, 2007). PL is now positioned as a determinant and pathway to health as per Cairney et al.'s (2019) evidence-informed conceptual model. Positioning PL within the narrative of health promotion and disease prevention provides legitimate potential opportunities to build inter-sectoral collaborations between PE, health promotion and public health (Cairney, Dudley, et al., 2019; Dudley et al., 2017).

Finally, FMS within the physical competence domain of PL has received global empirical attention through the developmental relationship model of MC (Robinson et al., 2015; Stodden et al., 2008) for lifelong PA participation. This was presented as a "*positive spiral of engagement*" (Stodden et al., 2008, p.297), whereby those with higher levels of MC were/are more likely to be involved in physical activities, and these experiences subsequently provide further opportunities to develop MC (Barnett, Cliff, Morgan, & van Beurden, 2013; Barnett, Morgan, van Beurden, Ball, & Lubans, 2011; Barnett, Lai, et al., 2016; McGrane, Powell, Belton, & Issartel, 2018; Stodden et al., 2008). Frequent PA participation relies on proficiency in FMS and in turn allows exposure to characteristics of PL (Ford et al., 2011; Tompsett et al., 2014). The aforementioned associations to lifelong participation in PA and associated health benefits warrant FMS inclusion in PE and PL (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Cliff et al., 2012; Hardy et al., 2013; Lubans et al., 2010; Tompsett et al., 2014). "*Individuals are physically literate when they have acquired the movement skills and confidence to enjoy a variety of sports and physical activities*" (Kriellaars, 2013, p.4), underlying and underpinning the importance of developing movement skills, especially for youth, that are broad and diverse (Dudley et al., 2017).

2.2 Fundamental Movement Skills (FMS)

2.2.1 FMS

Fundamental movement skills (FMS) are the basic observable building blocks or precursor patterns of the more specialised, complex movement skills required to successfully participate in organised and non-organised games, sports and recreational activities (Clark & Metcalfe, 2002; Hands, 2012). Examples exhibited during sport, exercise and PA include jumping, running, skipping (locomotor), catching, kicking, striking, throwing (object control), balancing, twisting and dodging (stability) (Department of Education Victoria, 1996; Gallahue et al., 2012). These skills attempt to cover the most representative or salient skills that, if mastered, will give children the best possible chance to successfully and persistently participate in a range of health-enhancing physical activities (Barnett, Stodden, et al., 2016). Children have the developmental potential to master most FMS by six years of age (Gallahue et al., 2012), while research has revealed that many children demonstrate mature patterns of motor skill development by the age of ten (Ulrich, 2000).

Fundamental movement or motor skills along with various other terms including motor [skill] proficiency, motor performance, motor ability, and motor coordination have been used to describe the motor domain (Robinson et al., 2015). In a recent systematic review of terminology used in 124 published articles, the term fundamental movement skills (n = 86, 69%) was found to be used more frequently than fundamental motor skills (n = 38, 31%). This may reflect a purposeful shift by researchers to use the more general term of “movement” instead of “motor”, recognizing that the terms are often used interchangeably to represent several different aspects of the global term MC (Logan, Ross, Chee, Stodden, & Robinson, 2018). In order to have good MC, an individual must be able to master many different kinds of motor skills (Sigmundsson, Trana, Polman, & Haga, 2017). Recent research has emphasised the relationship between MC and important health-related outcomes (Robinson et al., 2015). Essentially, highly developed MC during childhood and adolescence has the potential to foster lifelong functional independence and quality of life (Robinson et al., 2015).

Understanding movement skills that may be performed across the lifespan is an important consideration, specifically so that skill development in youth may be related to the general health and quality of life outcome in later years (Hulteen, Morgan, Barnett, Stodden, & Lubans, 2018). Whilst important, FMS may not reflect the broad diversity of skills utilised in PA pursuits across the lifespan (Hulteen et al., 2018). The term 'foundational movement skills', as proposed by Hulteen et al. (2018), may better reflect the broad range of movement forms that increase in complexity and specificity, and can be applied in a variety of settings. Thus, 'foundational movement skills' include traditionally conceptualized 'fundamental' movement skills and other skills (e.g., bodyweight squat, cycling, swimming strokes) that support PA engagement across the lifespan (Hulteen et al., 2018).

Promoting FMS is integral to a holistic view of motor development (Barnett, Stodden, et al., 2016). A systematic review of 21 articles undertaken with children and adolescents found a relationship between FMS competence and eight potential benefits, namely global self-concept, perceived physical competence, cardiorespiratory fitness (CRF), muscular fitness, weight status, flexibility, PA and reduced sedentary behaviour (Lubans et al., 2010). Furthermore, a more recent narrative review examining FMS and health-related outcomes found that developing proficient movement skills at a young age may have a positive impact on PA, physical fitness, body composition, self-belief, and executive functioning in later childhood and adolescence across typically developing children (Bremer & Cairney, 2016).

2.2.2 Correlates of Motor Competence in Children and Adolescents

Investigating the correlates of MC in children and adolescents is an emerging area in the field (Barnett, Lai, et al., 2016). A systematic review and meta-analysis conducted by Barnett, Lai, et al. (2016), the first of its kind, examined correlates under five broader categories, namely; (i) biological and demographic factors; (ii) behavioural attributes and skills; (iii) cognitive, emotional and psychological factors; (iv) cultural and social factors; and (v) physical environmental factors. Based on this review (which only included studies for which [gross] MC was chosen as the outcome variable for the analysis), the most examined correlates were biological and demographic factors; with age/grade (increasing/positive) a correlate of children's MC, while gender (male), weight status (healthy) and socioeconomic background (higher) were consistent correlates for certain aspects of MC only. In the behavioural attributes and skills category, PA and sport participation were the most investigated correlates, with some evidence for PA being a positive correlate of MC (Barnett, Lai, et al., 2016).

The meta-analyses of biological factors conducted by Barnett, Lai, et al. (2016) revealed small-to-medium effects for age and MC, specifically with locomotor, object control and stability skills. Interestingly, while there is strong evidence for age (or grade) as a positive correlate of children's MC, it is feasible that the relationship between age and MC might change across the developmental periods of early childhood, preschool, childhood and adolescence (Barnett, Lai, et al., 2016). Jaakkola and Washington (2013) actually found age to be a negative correlate for adolescent girls. This study suggested that the decline in MC was due to reduced opportunities to be active, as it was also found that girls' PA declined during this period (Jaakkola & Washington, 2013).

In relation to gender, there was strong evidence that being male was a positive correlate of object control skills, albeit no evidence was found that the gender of a child was a correlate of locomotor skills (Barnett, Lai, et al., 2016). According to Barnett, Lai, et al. (2016), these findings have potentially important intervention implications, as there is growing evidence of object control competence being a more salient predictor of PA and fitness behaviour than locomotor competence (Barnett, van Beurden, Morgan, Brooks, et al., 2009; Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2014; Vlahov, Baghurst, & Mwavita, 2014). Boys consistently have higher object control competence, which is a concern for females, as their PA participation levels also decline more than males during adolescence. Given that the evidence suggests that females have lower object control competence in comparison to males, they may also experience a negative spiral of disengagement, ultimately resulting in an unhealthy weight status (Barnett, Lai, et al., 2016; Stodden et al., 2008).

Other factors of interest that emerged from the aforementioned review included weight status, which had differential associations with aspects of MC. There was strong evidence that higher BMI was negatively correlated with stability skills and overall skill composite, however, these findings were not as apparent with the object control skills (Barnett, Lai, et al., 2016). Furthermore, while PA was identified as a positive correlate of overall skill composite (Jaakkola & Washington, 2013), interestingly, there was inconsistent and indeterminate evidence for PA being a correlate of object control or locomotor skill competence (Barnett, Lai, et al., 2016).

While investigating the correlates of MC in children and adolescents will help to identify potential mechanisms of change by identifying the factors that are likely to make a difference and also target specific groups for intervention (Sallis, Owen, & Fisher, 2008), it must be noted however that findings suggest that evidence for some correlates differs according to how MC is operationalized (Barnett, Lai, et al., 2016). It still remains unclear, therefore, which correlates should be targeted to ensure interventions are optimized, and whether or not, and for whom, targeted and tailored interventions should be developed (Barnett, Lai, et al., 2016).

2.2.3 FMS and Physical Activity

According to the World Health Organization (WHO), more than 80% of the world's adolescent population are insufficiently physically active, for example, 81% of the 11- to 17-year-old age cohort fail to meet the recommended PA guidelines for health (i.e., 60 minutes of moderate-to-vigorous physical activity (MVPA) per day) (World Health Organization, 2010, 2013, 2018a, 2018b). Previous data obtained from 105 countries worldwide also highlighted that 80% of adolescent youth aged 13-15 years failed to meet the recommended PA guidelines (Hallal et al., 2012). Ireland’s largest nationally representative research on childhood PA surveillance, entitled the ‘Children’s Sports Participation and Physical Activity’ (CSSPA) study (Woods et al., 2018), recently observed that only 10% of adolescents reach the recommended levels of PA for health. A recent study by De Meester, Stodden, Goodway, True, Brian, Ferkel, and Haerens (2018) on a relatively large group of 326 children found that children with higher levels of actual MC were 2.5 times more likely to meet the PA guidelines for health, when compared to their peers with lower levels of actual MC. As such, improving children’s actual MC is suggested as a strategy for overall higher levels of MVPA engagement during childhood and adolescence (De Meester et al., 2018). Furthermore, results of a seven-year study by Lima, Pfeiffer, Larsen, Bugge, Moller, Anderson, and Stodden (2017) on Danish children indicated a reciprocal longitudinal relationship between PA and MC (Lima et al., 2017).

A recently published longitudinal study confirms that the consequences of ineffective motor skills during childhood are far-reaching and may have a significant impact on PA participation over the lifespan (Lloyd et al., 2014). According to van Beurden, Zask, Barnett, and Dietrich (2002), childhood FMS proficiency underpins a physically active lifestyle. Given the fact that levels of PA participation decline dramatically during adolescence, for example, the Health Behaviour in School-aged Children (HBSC) study (Inchley et al., 2016) found that daily MVPA decreases significantly between 11 and 15 years of age, and these findings were observed among boys and girls in over thirty countries and regions (Inchley et al., 2016; Janz, Dawson, & Mahoney, 2000; Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). It is, therefore, of critical importance to improve MC in order to maintain adherence to PA participation during adolescence (Chen et al. 2017). Evidence suggests that competency in a range of FMS may serve as a protective factor against this trend (Barnett, van Beurden, Morgan, Brooks, et al., 2009; Lopes, Rodrigues, Maia, & Malina, 2011; Lubans et al., 2012).

PA is associated with protection from lifestyle diseases (Andersen, Riddoch, Kriemler, & Hills, 2011; Biddle, Gorely, & Stensel, 2004; Janssen & Leblanc, 2010; Lima et al., 2017; Voss et al., 2011). There is now strong cross-sectional and longitudinal evidence indicating that proficiency in FMS is positively associated with PA participation in children and adolescence (Fisher et al., 2005; Lima et al., 2017; Lloyd, Saunders, Bremer, & Tremblay, 2014; Lubans et al., 2010; Robinson et al., 2015; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). Holfelder and Schott (2014) in their systematic review observed an association between FMS (or other forms of MC) and PA in 12 out of 23 identified studies. Interestingly, Lubans et al., (2010) systematic review also noted that of the 13 studies that specifically examined FMS and PA in children and adolescents, 12 of these studies found a positive association between such variables. Essentially, higher levels of MC appear to foster more PA, and reciprocally, more PA appears to foster greater MC, which creates a positive spiral of engagement in PA during childhood and into adolescence (Lima et al., 2017; Stodden et al., 2008). FMS are identified as a primary underlying mechanism that promote positive engagement in PA (Barnett et al., 2011; Castelli & Valley, 2007; Stodden et al., 2008), and are deemed to be a key mediator for the changes in children's PA and cardio-respiratory fitness (Chan, Ha, & Ng, 2016; Cohen, Morgan, Plotnikoff, Barnett, & Lubans, 2015).

The general consensus within the motor development literature (Clark & Metcalfe, 2002; Haywood & Getchell, 2005; Seefeldt, 1980) is that MC is foundational to engagement in PA (Stodden et al., 2008). Specifically, proficiency in a range of FMS is considered to be a pre-requisite for a lifelong physically active lifestyle (Gallahue et al., 2012; Lubans et al., 2012; Haywood & Getchell, 2005). FMS proficiency, therefore, has the potential to influence PA behaviour (Goodway & Rudissill, 1997), and children who have established a base of FMS proficiency have the tools to be physically active (Butterfield, Angell, & Mason, 2012). With a broader repertoire of physical skills, children will have a greater chance of finding activities that they can do well in and enjoy participating in (Stodden et al., 2008; Welk, 1999).

2.2.3.1 Stodden's Model for Motor Competence and Physical Activity Engagement

Stodden et al. (2008) believe that developing MC or skilfulness is of paramount importance to understand why individuals choose to be either physically active or physically inactive. Moderately to highly skilled children will self-select higher levels of PA, whereas children with less-proficient levels of MC will engage in lower levels of PA (Stodden et al., 2008). In middle and later childhood, higher levels of MC has the potential to offer a greater motor repertoire for participants to engage in various forms of PA, sports, and games (Stodden et al., 2008). Children who attain a certain level of proficiency in FMS and continue to become skilful during middle childhood and adolescence also have more options to participate, and be successful in activities requiring adequate FMS during adulthood. These individuals will, correspondingly, demonstrate higher levels of health-related physical fitness and PA participation (Stodden, Langendorfer, & Roberton, 2009). Furthermore, highly skilled individuals in MC may increase their PA participation time (Wrotniak et al., 2006), and persist in activities that maintain higher levels of muscular strength, muscular power, and muscular endurance (Stodden et al., 2009).

Conversely, a lack of MC development is hypothesized to lead to a negative spiral of disengagement in PA, as children lack the competence and confidence to move, and are at an increased likelihood of not enjoying activities where they may not be successful (Robinson et al., 2015). Children who fail to acquire this movement base are less likely to be physically active, and show preference towards sedentary pastimes (Vameghi, Shams, & Dehkordi, 2013). In fact, children who do not develop FMS are often denied the opportunity to feel the intrinsic enjoyment of successful movement (Hands, 2012). Adolescents with low MC have diminished perceptions of their physical self and tend to avoid physical activities (McIntyre, Chivers, Larkin, Rose, & Hands, 2015).

Strategies to improve children and adolescents PA participation may need to first consider ensuring competence in the necessary range of FMS (Hardy et al., 2013). Researchers and practitioners must be cognisant, however, that there are simply not enough studies on adolescent populations to make any reasonable conclusions about the relationship between MC and PA strengthening over time (Robinson et al., 2015). Furthermore, while MC is suggested to be an important mechanism driving PA engagement, De Meester et al. (2018) highlight that it is not the only underlying mechanism and many other factors such as motivation to engage in PA, body weight status or parental support might affect children's actual engagement in PA (De Meester et al., 2018).

2.2.4 The Age-Related Development of FMS

The phases of motor development (Figure 2.1) are classified as the reflexive (4 months to 1 year old), rudimentary (1–2 years old), fundamental (2–7 years old) and specialized (7 years old and up) movement phases (Goodway, Ozmun, & Gallahue, 2020). Clark and Metcalfe (2002) introduced the 'Mountain of Motor Development' as a metaphor to describe these four phases (Hoeboer et al., 2016). As children move from early to late childhood at the fundamental movement stage, they

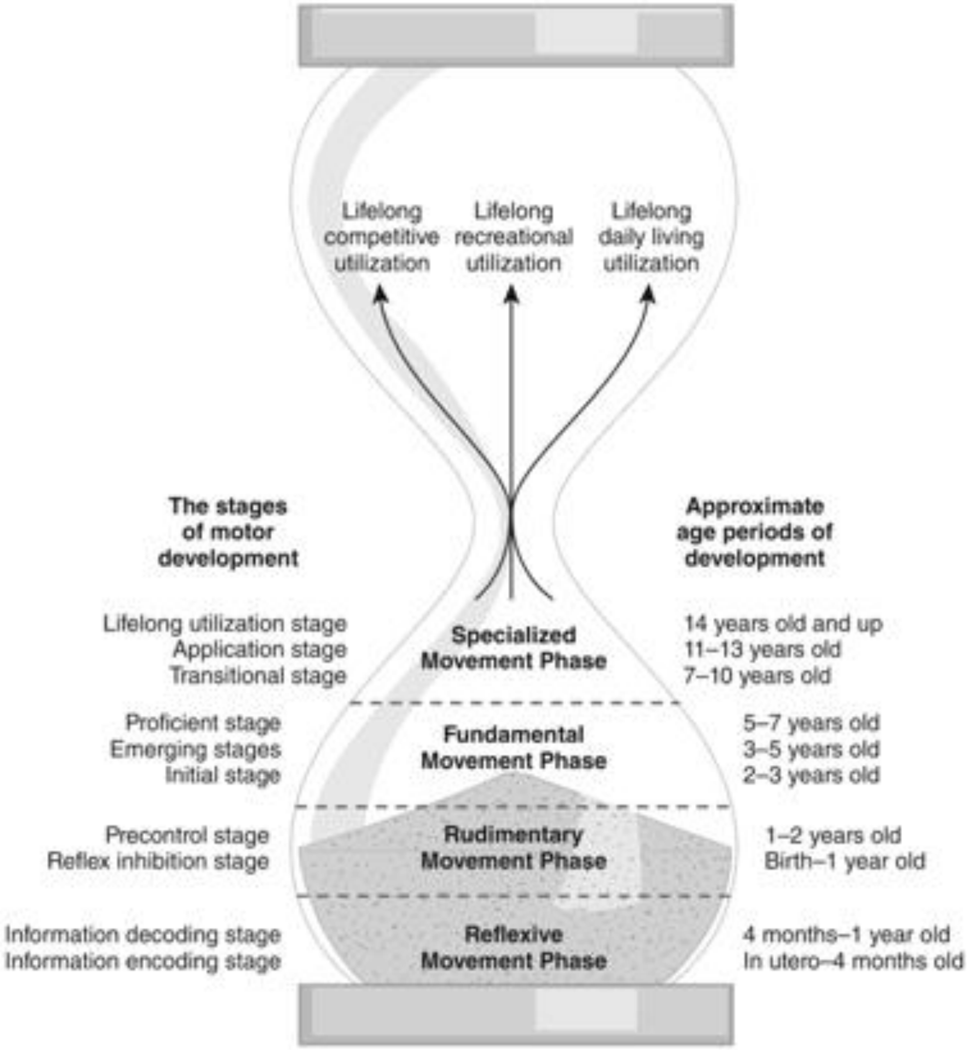

Figure 2.1: The phases and stages of motor development (Goodway et al., 2020, p.178).

begin building upon previously learned movements from the reflexive and rudimentary movement phases. Through this age-related sequential progression, children are preparing for the acquisition of more advanced skills within the specialized movement stage (Gallahue et al., 2012).

The evidence base, therefore, suggests that early childhood is a critical period and opportunity for the development of FMS proficiency (Hardy, King, Farrell, Macniven, & Howlett, 2010). Failure to take advantage of this critical window characterised by play (i.e., practice opportunities in both undirected/unstructured and directed/structured settings) which facilitates cognitive and affective growth and subsequent development of fine and in particular gross motor skills can often make it more difficult to attain higher levels of motor skills later in their life (Gallahue & Cleland Donnelly, 2003). The importance of the FMS acquisition phase is highlighted as a time to create a broad base of skill competencies, alongside promoting the greatest potential for skill transfer (Hulteen et al., 2018). It is widely recognised that children with a stronger FMS base will have a greater repertoire of skills to apply across a greater variety of physical activities (Haubenstricker & Seefeldt, 1986; Hulteen et al., 2018). As individuals learn more advanced or 'transitional skills', the levels of competency needed are higher due to the additional constraints and demands of specific activities (Hulteen et al., 2018; Langendorfer, Roberton, & Stodden, 2011).

FMS are believed to develop naturally in children and are often recognized as developing during the pre-pubescent years (Burton & Miller, 1998). It is possible, therefore, that FMS improvements may occur as a developmental change in the absence of skill-specific training (Capio, Sit, Eguia, Abernethy, & Masters, 2015). Conflicting evidence indicates that improvements in FMS proficiency could also be attributed to skill-specific training, and not only to developmental change (Capio et al., 2015). According to Clark (2005), FMS competency does not develop naturally through maturational processes, or as a result of age. Barnett et al. (2016), for example, have highlighted that it is only through instruction that significant improvements in FMS are seen (Barnett, Stodden, et al., 2016). Previous authors have also specified that FMS need to be learned, practiced and reinforced (Goodway & Branta, 2003; Haywood & Getchell, 2009; Logan, Robinson, Wilson, & Lucas, 2012; Payne & Isaacs, 2002; Robinson & Goodway, 2009; Valentini & Rudisill, 2004). A sample of meta-analyses and reviews have similarly concluded that motor skills need to be taught and reinforced, and do not develop 'naturally' over time (Logan et al., 2012; Morgan et al., 2013; Riethmuller, Jones, & Okely, 2009; Robinson et al., 2015).

Children must be provided with quality instructions, feedback, and sufficient opportunities for practice to develop FMS proficiency (Hands, 2012). This specification requires teachers to be equipped with effective instructional and assessment approaches to bring about change in children's motor skill development (Chan et al., 2016). Indeed, findings from Hardy et al. (2010), and more recently Lester, McGrane, Belton, Duncan, Chambers, and O'Brien (2017), highlight the need to provide structured opportunities which facilitate children's and adolescents acquisition of FMS.

2.2.5 FMS Levels in Children and Adolescents

As mentioned, childhood is the optimal time to develop FMS and the primary school years represent the 'golden years' of motor development (Gallahue & Ozmun, 2006; Lander, Hanna, et al., 2017; Lander, Morgan, Salmon, Logan, & Barnett, 2017; Lubans et al., 2012). Mastery of FMS components in this age group is crucial for children to graduate with a level of competence, that enables them to live a physically active and healthy lifestyle in early secondary school years (Chan et al., 2016; Hardy et al., 2013). Alarmingly, many children finish primary school without achieving mastery (i.e., displaying correct performance of all components of a skill) (Booth, Denney-Wilson, Okely, & Hardy, 2005; O'Brien, Belton, & Issartel, 2016; van Beurden et al., 2002) in a range of FMS (Lubans et al., 2012), and are often unprepared for what is predominately a sports-based PE curriculum in secondary school (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Hardy et al., 2013; Lander, Hanna, et al., 2017), while those from disadvantaged backgrounds often demonstrate the lowest competency levels (Lubans et al., 2012; van Beurden et al., 2002).

Recent research has shown that the majority of post-primary Irish youth are insufficiently active and fail to reach a level of proficiency across basic movement skills (Belton, O'Brien, Meegan, Woods, & Issartel, 2014; O'Brien et al., 2016; O'Brien, Duncan, Farmer, & Lester, 2018; O'Brien, Issartel, & Belton, 2013). Belton et al. (2014) reported that the majority of youth (99.5%) in Ireland failed to reach a level of mastery across key FMS, indicating that basic movement skill proficiency is low. More recently, Lester et al. (2017) found that no participant (n = 181) displayed mastery level across ten FMS assessed in a cross-sectional, mixed gender sample of Irish adolescent youth (mean age: 14.42 ± 0.98 years (age range: 12.31–16.41 years old)). In Europe, a recent study on Portuguese children (N = 200; mean age: 7.6 ± 1.4 years (age range: 5–9 years old)) from five primary schools in two regions found an increase in MC with age (Lopes, Saraiva, Gonçalves, & Rodrigues, 2018), albeit international research suggests that FMS proficiency amongst children has declined in the past 15 years, with more-children performing FMS at a low-mastery level (Burrows, Keats, & Kolen, 2014). It is, therefore, essential that we adequately assess whether or not our children are progressing in terms of FMS, relative to their age. It is, however, important to note that FMS and the process of motor development as a whole is age-related, yet not always age determined (Gallahue et al., 2012; O'Brien et al., 2016).

2.2.5.1 Motor Competence Thresholds

Haubenstricker and Seefeldt (1986) indicated there might be a threshold level of MC (Seefeldt, 1980) above which a child will be more likely to engage in various types of PA when they are able to successfully participate (i.e., due to adequate MC levels) in a greater variety of physical activities. Below this threshold, a child is less likely to engage in such activities (Haubenstricker & Seefeldt, 1986), as he/she would not have the prerequisite skill level to be successful, and as a result, lack the confidence and motivation to engage in physical activities (De Meester et al., 2018). Children with MC levels below the proficiency barrier may invariably demonstrate decreased success and enjoyment in various activities across childhood, leading to subsequent higher dropout rates of sports and PA over time (De Meester et al., 2018; Stodden, True, Langendorfer, & Gao, 2013). As children with low MC experience more difficulty when attempting challenging movement tasks (Seefeldt, 1980), they may be more at risk for a physically inactive lifestyle, when compared to their peers with higher MC levels (De Meester et al., 2018; Wrotniak et al., 2006).

Research has previously suggested that jumping and running are the most commonly used locomotion/locomotor skills (i.e., movement from one point to another), that children engage in both in structured and unstructured play (McKenzie et al., 2002). Locomotor skills also require certain levels of explosiveness and strength to be executed properly (Kalaja, Jaakkola, Liukkonen, & Digelidis, 2012).

In terms of object control skills (i.e., manipulation of an object such as a ball) kicking, catching and overhand throwing have been shown to be significant predictors of children's PA (Barnett, van Beurden, Morgan, Brooks, et al., 2009). Although locomotor skills generally develop earlier than object control/manipulation/ball skills (Robinson et al., 2015), children with object control skill proficiency are more likely to play organised and non-organised sports, and also are at an increased likelihood of participating in specific physical activities during the adolescent years (Barnett, Lai, et al., 2016; Barnett et al., 2009; Chen, Hammond-Bennett, & Hypnar, 2017; Hardy et al., 2010; Okely et al., 2001). A cross-sectional study by Barnett, Morgan, van Beurden, Ball, and Lubans (2011), for example, observed a positive feedback association between object control and MVPA in 215 Australian adolescents (mean age: 16.4 ± 0.6 years) (Barnett et al., 2011). Development of proficiency in object control skills is a stepping stone to help learn PE content with greater success and enjoyment in adolescence (Barnett, Lai, et al., 2016; Barnett et al., 2009; Chen et al., 2017; Lander, Eather, Morgan, Salmon, & Barnett, 2017). Object control skills can be seen as more complex than balance skills, for example, because they raise issues on perceptional demands (Nessler, 1973), and thus require more practice to be improved (Kalaja et al., 2012). Chen et al. (2017) suggests that PE teachers need to provide more learning opportunities for children to learn and practice a variety of object control skills such as hand dribbling, dribbling with feet, kicking, overarm throwing, underhand throwing, volleying with body parts, and striking skills with rackets and bats (Chen et al., 2017). Given the declining trend of PA participation among adolescents (Sallis, 2000), it is critical to develop children's motor proficiency, particularly in object control skills (Chen et al., 2017).

2.2.6 Measurement/Assessment of FMS

Different batteries for FMS and MC assessment have emerged around the world, all testing slightly different forms and groups of skills (Barnett, Stodden, et al., 2016; Basman, 2019; Cools, De Martelaer, Samaey, & Andries, 2009). Test batteries focus on skills that require practice and training (i.e., ontogenetic activities), and which promote engagement in a broad range of culturally relevant and socially driven activities (Barnett, Stodden, et al., 2016). Accurate and comprehensive assessment of MC is becoming increasingly important, as it provides researchers and practitioners with a better understanding of the relationship between MC levels and possible health outcomes (Logan et al., 2017).

Two types of assessment measures exist: 1) process and 2) product – both assessment formats are used to determine MC levels. While product-oriented assessments evaluate the outcome of movement, typically identified as a quantitative score (e.g., speed, distance or number of successful attempts) (Logan, Barnett, Goodway, & Stodden, 2017), the difficulty with many product measures is that they do not examine the developmental movement process that resulted in the movement product (Stodden et al., 2008). Stodden et al. (2008) have previously argued that product scores are generally not a valid developmental measure of MC, although they concede that the resultant product scores such as ball speed in kicking, throwing and jumping distances are valid because of their ballistic skill-specific nature (Stodden et al., 2008). In contrast, process-oriented assessments evaluate how a movement is performed (i.e., technique used) based on the demonstration of behavioural criteria, allowing researchers to identify specific aspects of movement for each child that need to be improved upon (Logan et al., 2012). Process-oriented assessment tools involve the identification of qualitative patterns of movement (Logan et al., 2017).

The forthcoming sub-sections will introduce and review assessment tools often used in the literature, specifically two examples of process-oriented assessment tools; the Test of Gross Motor Development-Second Edition (TGMD-2) (Ulrich, 2000), including reference to other versions of the test, and Get Skilled: Get Active (GSGA) (NSW Department of Education and Training, 2000), as well as an example of one product-oriented assessment tool, namely the Körperkoordinationstest für Kinder (Body Coordination Test for Children, KTK) (Kiphard & Schilling, 1974, 2007).

2.2.6.1 Test of Gross Motor Development (TGMD)

The TGMD (Ulrich, 1985) is a norm-referenced, process-oriented test battery that qualitatively measures performance and competence in a set of motor skills deemed essential for predicting participation in PA and sport. Similarly, having been normed on a sample of 1208 people in the USA, the TGMD-2 (Ulrich, 2000), has a high degree of reliability and established construct validity (Cools et al., 2009; Evaggelinou, Tsigilis, & Papa, 2002; Wong & Cheung, 2010), with the TGMD-2 alone now having over 1,000 research citations (Ulrich, 2017).

The TGMD-2 is a gross motor skill proficiency process oriented method of assessment that refers to a criterion and a norm (Cools et al., 2009). The TGMD-2 provides assessment criteria for skill execution using the Component Stage Theory (CST) through the mastery or proficiency criteria model (Hands, 2002). Although

CST states that body components develop at their own rate, and therefore should be assessed independently, this less complex approach to assessment using CST describes the key actions of the main body parts for the proficient form of the action (Hands, 2002), to determine whether a child does or does not demonstrate a specific component. Essentially, the breakdown of skills into components provides a good foundation for measuring change over time and the possibility of tailoring an intervention accordingly (Cools et al., 2009; O'Brien et al., 2016; van Beurden et al., 2003). Although the TGMD-2 does not measure the outcome of a given movement sequence, it is implicitly assumed that the underlying process is associated with successful outcomes (Rudd et al., 2016). Indeed, empirical evidence suggests strong associations between skill process and skill outcomes (Rudd et al., 2016).

The TGMD-2 assesses twelve skills which are divided into two sub-domains (as outlined previously): locomotor (run, leap, hop, gallop, slide, and horizontal jump) and object control (catch, kick, overhand throw, underhand roll, striking a stationary ball, and stationary dribble). Each of these skills is broken down into various components which are assessed to determine proficiency levels in performing the given skill. It has been designed to assess the FMS of children aged 3-10 years and is widely used due to its high validity and reliability (Cliff, Okely, & Magarey, 2011; Hardy et al., 2010; O'Brien et al., 2016). The TGMD-2 therefore provides a good evaluation of children's gross motor competency (Ulrich, 2000). The TGMD-2 was developed primarily to focus on the identification and screening of developmental delay (Logan et al., 2017), that is, if children were delayed in demonstrating FMS competence. The capability of the TGMD-2 to identify developmental delay is consistent with other assessment batteries, with the same purpose (Logan, Robinson, Rudisill, Wadsworth, & Morera, 2014; Valentini et al., 2015). Considering also that the TGMD-2 has been recommended for use following a meta analysis (Logan et al., 2012) and has also been validated for various populations across countries, ethnic groups and groups with specific disabilities (Barnett et al., 2019; Houwen, Hartman, Jonker, & Visscher, 2010; Issartel et al., 2017; Wong & Cheung, 2010), it is logical to choose it above other assessment tools.

A limitation of the TGMD-2 is that it does not assess stability (Gallahue & Ozmun, 2006). It is also worth noting that the sensitivity to detect advanced skill level is lowest for the TGMD-2 (Logan et al., 2017), when compared to other process-oriented MC assessments, specifically the Get Skilled: Get Active (GSGA) instrument. Therefore, the potential 'ceiling effect' with the TGMD-2 is a limitation, as associated with many other qualitative assessments. A possible explanation for this may be that the instrument, as highlighted above, is only recommended through to age ten (Logan et al., 2017; Ulrich, 2000). Furthermore, it has been stated that the assessment of some skills using the TGMD-2 could be potentially identified as sport-specific (Barnett, Ridgers, Zask, & Salmon, 2015).

Finally, given that FMS not only require assessment and development during primary school (age: approximately 4-12 years) but also into secondary school (age: approximately 12-18 years), it is imperative that FMS proficiency levels may be measured and tracked throughout childhood and adolescence. Results of a recent cross-sectional observational study by Issartel et al. (2017), which assessed the reliability and validity of the TGMD-2 with an adolescent population, proposed a reduction in the number of skills to just seven (run, gallop, hop, horizontal jump, bounce, kick, and underhand roll) (Issartel et al., 2017). Specifically, results suggested that some tasks were deemed to be simple and even artificial, considering the theoretically expected maturation level of FMS proficiency for this age cohort. Furthermore, based on the developmental continuum, adolescents may not have reached the appropriate FMS proficiency level of certain skills but may have moved both biologically and psychologically beyond the skills' objective, as currently described in the TGMD-2, and therefore consideration should be given towards potentially modifying the objectives of some skills for different age cohorts (Issartel et al., 2017).

2.2.6.1.1 TGMD-3

The most recent revision, the TGMD-3 (Maeng, Webster, Pitchford, & Ulrich, 2017; Ulrich, 2017; Webster & Ulrich, 2017), has seen a number of changes, such as the object control subset renamed ball skills subtest. Within this subset, the underhand roll has been omitted and the underhand throw added, as the rationale for this skill's inclusion is that it seems to reflect a skill more prevalent in games and sports. Furthermore, a one-hand strike, as is used worldwide in racket sports, has been added to the ball skills subset, while the two-hand strike has also been retained. In the locomotor subset, the skip has been reinstated from the original TGMD, with the leap being removed. As a result of these changes, there are now six locomotor skills and seven ball skills in the TGMD-3. According to Ulrich (2017), the increase in the number of ball skills on the TGMD-3 is justified given that public health research suggests that a child's ball skill competency relates to children's future level of PA (Ulrich, 2017). Psychometric properties of the TGMD-3 have been reported with high levels of reliability and validity (Burns & Fu, 2018; Estevan et al., 2017;

Webster & Ulrich, 2017) The continuing popularity of this assessment as a whole is due to the ease of administration and scoring, norm-referenced scores for diagnostic evaluation, and the criterion referenced and process-oriented skills that can assist in designing individualised motor development programmes (Maeng et al., 2017).

2.2.6.2 Get Skilled: Get Active (GSGA)

The Australian GSGA (NSW Department of Education and Training, 2000) is an appropriate process-oriented qualitative assessment tool for evaluating FMS proficiency in typically developing children. The GSGA assessment tool was developed to coincide with the GSGA FMS teaching resource/checklists. GSGA has some capacity to detect advanced skilfulness, and it appears to be more closely aligned with product-based scores, than the TGMD-2 (Logan et al., 2017).

The GSCA consists of twelve motor skills including the sprint run, leap, dodge, vertical jump, hop, side gallop, skip (i.e., all locomotor skills), catch, overhand throw, kick, two-handed forehand strike (i.e., all object control skills), and static balance (i.e., stability skill). The twelve skills were included as they are considered to collectively form the foundation for the development of sport specific skills (NSW Department of Education and Training, 2000). Each skill is broken down into observable and behavioural components that allow for the estimation of the proficiency level for each skill (Okely & Booth, 2004). For each skill, a number of introductory performance criteria (either two or three) as well as additional fine-tuning components (between 2-4) are provided, allowing skills to be assessed at two different levels of difficulty. Depending on the level of difficulty as well as the number of skills chosen to be assessed, a total skill, subset and overall test score can be obtained. As mentioned above, teachers also receive a checklist which they can use to help assess performance (NSW Department of Education and Training, 2000).

GSGA is seen as a popular, appropriate and reliable assessment tool to assess gross motor skill proficiency in children and adolescents (Barnett et al., 2010; Okely & Booth, 2004). Although, it is a well-utilised instrument in Australia and the development of GSGA appears to have been thorough and meticulous (Barnett et al., 2010; Barnett, van Beurden, Morgan, Brooks, et al., 2009; Hardy et al., 2013), aside from one publication on interrater reliability (Barnett, van Beurden, Morgan, Lincoln, et al., 2009), no previous validity, test retest reliability or normative scores have been published in regard to GSGA (Logan et al., 2017). Therefore, a major weakness of the GSGA resource is the limited evidence available in relation to its reliability and validity, with Barnett et al. (2010, p. 168) stating that it's "*validity was not assessed in terms of whether the specialised skill features reflected proficient performance compared to that specified in the current literature*". Furthermore, checklists included in the resource also fail to provide guidelines to the number of trials that are required and/or if scores across performances should be summed or if the best performance should be used as an indicator of proficiency level while normative data is not provided with this resource.

2.2.6.3 Körperkoordinationstest für Kinder (KTK)

The KTK (Body Coordination Test for Children) (Kiphard & Schilling, 1974, 2007) is a product-oriented test battery, suitable for evaluating MC levels in typically developing children and adolescents, between the ages of five and fourteen years (Cools et al., 2009; D'Hondt et al., 2013; Graf et al., 2004; Laukkanen, Pesola, Havu, Sääkslahti, & Finni, 2014; Lima et al., 2017; Morrison et al., 2012). It is a standardised instrument, with good psychometric properties, excellent test-retest and interrater reliability (all r-values > 0.85), and good-to-excellent intrarater reliability (0.80 < r < 0.96) (Bardid, De Meester, et al., 2016; Kiphard & Schilling, 1974, 2007; Vandorpe et al., 2011). The KTK is therefore a highly reliable and valid instrument to assess gross motor and dynamic balance skills (Kiphard & Schilling, 2007; Smits-Engelsman, Henderson, & Michels, 1998; Vandorpe et al., 2011) and a valuable tool for assessing MC (Fransen et al., 2014). Established KTK cut points (Kiphard & Schilling, 2007) are generally used to evaluate children's and adolescents' MC and to detect possible delays in their motor development (Kiphard & Schilling, 2007), although the test battery has been used to evaluate MC in a wide variety of settings and target groups, ranging from clinical populations, typically developing children and adolescents, to young elite athletes (D'Hondt et al., 2013; De Meester et al., 2016; Opstoel et al., 2015; Pion, Fransen, Lenoir, & Segers, 2014).

The administration of the KTK takes approximately twenty minutes per child, and involves the completion of four independent tests or subtests: 1) walking backwards along balance beams of decreasing width (6.0 cm, 4.5 cm, 3.0 cm), 2) moving sideways on wooden boards for 20 seconds, 3) jumping (two-legged) from side to side over a slat for 15 seconds, and 4) hopping (one-legged) over foam obstacles with increasing height in consecutive steps of 5 cm. Raw scores for each of the four tests or subtests are converted to motor quotient (MQ) scores, which can then be compared to normative scores, standardized based on age and gender. MQ scores are summed and converted to give a total MQ score, providing an indication of a child's overall gross motor coordination (Iivonen, Sääkslahti, & Laukkanen, 2016; Kiphard & Schilling, 1974, 2007). This score is then used to classify children into one of five categories: impaired, poor, normal, good and high.

Limitations of the KTK assessment tool include its inability to determine locomotor and/or object control proficiency (with only an overall value representative of gross motor skill proficiency produced), while normative scores are based on the performance of 1228 typically developing children from a German population only, with values obtained over forty years ago.

2.2.6.4 The Future of Meaningful Motor Competence Assessment

According to Rudd et al. (2016), if used individually, commonly used assessment batteries provide only a limited view of the overall MC of children. To obtain a more holistic picture of the movement competencies of children, future research should examine both FMS and body coordination skills. Body coordination movement activities focus on moving and controlling the body in gravity defying ways to encourage the development of movement fluency, rhythm, timing and body strength (Rudd et al., 2016). Suitable examples of such activities would be gymnastics, dance and martial arts and these should be experienced alongside learning key object control and locomotor skills. Together, they will promote a strong foundation in overall MC (Rudd et al., 2016). It is possible that while assessments are able to detect developmental delay, they may not be able to adequately discriminate levels of skilfulness in typically developing children. Thus, existing assessments may not provide adequate sensitivity in the research context to determine how FMS competence relates to health outcomes and behaviours (Stodden et al., 2008).

Furthermore, Rudd et al. (2016) highlights that MC is a multidimensional concept and may not be recorded adequately by one test battery. There is an inherent identified need apparent within current literature for a MC assessment that measures both process- and product-oriented outcomes (Robinson et al., 2015; Rudd et al., 2016; Utesch, Dreiskämper, Naul, & Geukes, 2018). Current interventions have typically only been designed to address selected aspects of MC, and may therefore be failing to capture all aspects of children's MC. The development of assessments that measure both process- and product-oriented outcomes will not only allow researchers to comprehensively capture levels of MC in human movement and how MC relates to other variables, but they also have the potential to provide researchers with a single assessment that captures multiple salient descriptors of MC (Logan et al., 2017; Robinson et al., 2015).

2.2.7 FMS Interventions

2.2.7.1 The School and Physical Education Context for FMS Interventions

Movement skill interventions consist of planned movement activities that are developmentally and instructionally appropriate (Logan et al., 2012). Following a systematic review of 19 interventions, Morgan et al. (2013) highlighted that the most successful programmes aimed at increasing FMS utilised PE specialists or highly trained classroom teachers, as well as providing developmentally appropriate activities. According to Barnett et al. (2016), an authentic learning environment is one that is developmentally appropriate, based on the individual's developmental level. For effective FMS teaching, students should have the opportunity to practice their movement skills using a variety of equipment, such as with bean bags and different-sized balls for catching and throwing, as this equipment uses a variety of movement forms, adding complexity to the skill (Chan et al., 2016; Griggs, 2012).

The capacity of schools to enhance children's FMS is limited at best (Mitchell et al., 2013), due to the limited contact time with students within the PE setting, as well as the lack of PE specialists, particularly at primary level. Research suggests that primary or elementary school PE is often ineffective, owing to a number of institutional, as well as teacher-related barriers (Lander, Hanna, et al., 2017; Morgan & Hansen, 2007, 2008). As a result, skill deficits can remain largely unidentified as students' progress to high (middle) school (Year 7, approximately 12–13 years of age), and opportunities to improve FMS may have been missed (Ehl, Roberton, & Longendorfer, 2005; Lander, Brown, Barnett, & Telford, 2015; Lander, Hanna, et al., 2017). That said, a school-based teacher-led intervention is an effective way to improve FMS competencies. Increasing evidence shows that school-based FMS interventions delivered by PE teachers, alongside the provision of professional learning opportunities for teachers are effective (Chan et al., 2016; Cohen et al., 2015; Mitchell et al., 2013; Morgan et al., 2013). When teachers are supported to teach FMS, improvements can be substantial (van Beurden et al., 2003). This process involves long-term professional development of teachers, the employment of specialist PE consultants (Hardy et al., 2012) and a bottom up approach (Belton et al., 2014; Green & Kreuter, 1991) to help make FMS a curricular priority within schools.

Consistently, intervention results, including previous systematic reviews and meta-analyses, illustrate a significantly positive association between participation in school-based motor skill programmes, and FMS proficiency in children (Logan et al., 2012; Morgan et al., 2013; Valentini et al., 2016). The school-based PE setting is now considered an opportunistic setting where young people can accumulate vigorous PA, and learn important generalisable FMS (McKenzie & Lounsbery, 2009). To help students demonstrate competency in motor skills and movement patterns, PE teachers should provide students with a quality PE programme, which is a powerful vehicle for equipping children with competency in motor skills and movement patterns (NASPE, 2014, 2016; Chen, Hammond-Bennett, & Hypnar, 2017; Clark, 2005; Graham, Holt/Hale, & Parker, 2013; Lubans et al., 2010). QPE provides students with a variety of developmentally appropriate and fun activities by using effective instructional strategies to maximize students' learning time, and participation in MVPA during a PE lesson (NASPE, 2014, 2016; Chen et al., 2017; Clark, 2005; McKenzie, Alcaraz, & Sallis, 1998; McKenzie et al., 1996, 2002; McKenzie, Sallis, Kolody, & Faucette, 1997; Prochaska, Sallis, Slymen, & McKenzie, 2003; Sallis et al., 1997). There is now considerable data to suggest that the prescription of FMS programmes during PE (Kalaja, Jaakkola, Liukkonen, & Digelidis, 2012; Martin, Rudisill, & Hastie, 2009; McGrane, Belton, Fairclough, Powell, & Issartel, 2018; Mitchell et al., 2013; O'Brien et al., 2013) may significantly enhance motor skill proficiency.

2.2.7.2 Case Study Approaches to FMS Interventions

International research based studies such as 'Project Energize' (Mitchell et al., 2013) in New Zealand, as well as GSGA (NSW Department of Education and Training, 2000) and 'Move It Groove It' (MIGI) in Australia (van Beurden et al., 2003) have highlighted that FMS can be positively integrated for children and early adolescents within the PE environment (Mitchell et al., 2013; van Beurden et al., 2003). These studies have paved the way for the implementation of other intervention programmes in response to the identified needs within the population.

At the primary school level in Ireland, ‘Project Spraoi’ (Coppinger, Lacey, O’Neill, & Burns, 2016), a school-based health promotion intervention, based on ‘Project Energize’ (Rush et al., 2016), was the first study to examine the effect of a specifically tailored intervention at improving FMS proficiency among children (Bolger et al., 2019). FMS proficiency was measured using the TGMD-2 (Ulrich, 2000) and data were collected from 6- and 10-year-old cohorts (N = 357), as these age groups have been highlighted as important developmental periods during childhood, from two intervention schools (n = 195) and age-matched groups from one control school (n = 162), in south Ireland. The 26-week intervention involved bi-weekly FMS and PA sessions delivered by qualified specialists (i.e., Energizers), along with on-going teacher professional development and an at-home practice component encouraging parental participation. Significant increases were found in locomotor standard score, object control standard score, and gross motor quotient (GMQ) score among the 6-year-old and 10-year-old intervention groups, while significant decreases were observed among the respective control groups (Bolger et al., 2019). Results from this multi-component, school-based intervention provides further evidence for the effectiveness of FMS interventions among primary school children (Bolger et al., 2019).

Similar findings were also observed at post-primary level in the recent ‘Youth-Physical Activity Towards Health’ (Y-PATH) (Belton, O’Brien, McGann, &

Issartel, 2019; Belton et al., 2014; McGrane, Belton, et al., 2018; O'Brien, Belton, & Issartel, 2015; O'Brien et al., 2013) programme, which highlights the positive integration of FMS and PA during the provision of PE for adolescent youth (Belton et al., 2019, 2014). Indeed, O'Brien et al. (2013) observed that the structured implementation of a specifically tailored PE intervention can significantly improve FMS proficiency amongst adolescent youth. Furthermore, O'Keeffe et al. (2007) implemented an intervention for senior high school students (N = 46; mean age: 15.8 ± 0.60 years) consisting of two 30-minute lessons per week for a period of three weeks (i.e. six PE classes) and found that students who were taught the overarm throw improved skills in throwing, but also transferrable skills of the overhead clear in Badminton and the javelin throw in athletics (O'Keeffe et al., 2007).

Although Kalaja et al. (2012) highlighted that there is a lack of research overall with motor skill interventions implemented among adolescents, research confirms that it is possible to develop junior high school students' FMS through leaping, running, balancing, dribbling, and throwing within a specific PE intervention, while also preventing the typical decline in PA within junior high school students (Kalaja et al., 2012). The participants of this study consisted of 446 Finnish Grade 7 students (aged 13 years old) and specifically, the experimental group consisted of 199 students (110 girls and 89 boys) of one school, from nine classes, taught by four PE teachers. The intervention consisted of 33 sessions (covering almost the whole academic year), each of 25 minutes' duration, and made up of three week blocks focusing on one area of FMS (i.e., locomotion, object control, or balance), within naturalistic PE classes. The FMS training sessions were scheduled at the beginning of the PE class and, therefore, were marketed to the students as prolonged warm-up periods. An interesting finding of Kalaja et al. (2012) was that balance skills, rather than locomotor and object control skills developed during the intervention.

A pilot study by Capio et al. (2015) also suggested that by targeting FMS proficiency, children (n = 25) are likely to have heightened weekend PA. Although there was no overall main effect of FMS proficiency on weekday PA, positive changes were observed on weekend PA across the three identified PA categories of sedentary, light physical activity (LPA) and MVPA, as a result of 45 minutes of FMS integration once per week for four weeks. Children, with and without disability, who underwent FMS training were found to have decreased sedentary time and heightened LPA and MVPA time on weekends. This is significant, as a recent study by Belton, O'Brien, Issartel, McGrane, and Powell (2016) points to the weekend midday and afternoon periods as particular time blocks to target for intervening with physically inactive youth (Belton et al., 2016).

Evidence-based recommendations have highlighted that movement skills training should be based on a sound theoretical framework (Riethmuller et al., 2009). The FMS training programme implemented by Capio et al. (2015) was based on the errorless motor learning model (Maxwell, Masters, Kerr, & Weedon, 2001), which constrains the environment to minimize the amount of practice errors (Poolton, Masters, & Maxwell, 2005). For example, in a throwing task, the learner might practice from close to the target (e.g., 1 m) and gradually move away from the target as practice trials accumulate (Capio, Poolton, Sit, Holmstrom, & Masters, 2013; Poolton, Masters, & Maxwell, 2007). This might be considered for future explorations that involve movement training, as it is deemed to be an appropriate framework for FMS training of children, particularly as this approach could accommodate learners' variations of ability. It is believed that greater experiences of success during practice could promote heightened self-efficacy among children (Capio et al., 2015).

Results by Rudd et al. (2016) and work by Ericsson (2008) suggest that children's MC encompasses a number of additional components besides FMS, and that interventions based solely on the development of FMS might not provide adequate development of body coordination, resulting in a lack of overall MC in the long-term. For children to be truly competent, they should participate in a wide range of activities (Rudd et al., 2016). This is supported by evidence indicating that elite athletes do not specialise in their specific sport from an early age but participate in a wide range of activities throughout childhood and specialise when they are older (Côté & Fraser-Thomas, 2007; Rudd et al., 2016). To this extent, children should be encouraged and given the opportunity by parents, schools and clubs to take part in task-oriented body coordination movement activities, which focus on moving and controlling the body in gravity defying ways to encourage the development of movement fluency, rhythm, timing and body strength (Rudd et al., 2016). Examples of these activities include gymnastics, dance and martial arts. Activities such as these should be experienced alongside learning key object control and locomotor skills, learned through deliberate play (Côté & Fraser-Thomas, 2008) and traditional sports. Together, they will promote a strong foundation in overall MC (Rudd et al., 2016).

2.2.7.3 Considerations for Physical Education Teachers in FMS Development

One of PE's unique contributions to children is the positive emphasis towards the education of motor skill performance (Martin et al., 2009). As suggested by Martin et al. (2009), it is important to recognize that children do not acquire FMS as a result of the maturation process, but rather through a teacher or coach's instruction and practice. According to Lander et al. (2017), teacher competence may largely underpin the overall effectiveness of FMS programmes (Lander, Hanna, et al., 2017). Effective teaching is considered the single most powerful influence on student achievement in PE (Bailey, 2006; Hattie, 2009; Lander, Hanna, et al., 2017; Lee, Burgeson, Fulton, & Spain, 2007), with substantial improvements found when teachers are supported to teach FMS (Chan et al., 2016; Mitchell et al., 2013; van Beurden et al., 2003). Therefore, enhancing teacher competence in FMS teaching should be a focus in future teacher training programmes (Lander, Hanna, et al., 2017).

It's imperative that PE teachers are encouraged to develop PE class activities in which students may improve their FMS in order to promote their PA. Thus, PE teachers must create motivational climates that support the learning of movement skills (Martin et al., 2009). Indeed, Kalaja et al. (2012) recommend that the planning of an intervention should represent a cooperative process, notably that PE teachers are actively involved in the planning of PE lessons. Activities within FMS sessions should also be planned to include sufficient differentiation for the holistic inclusion of students with different skill level abilities (Kalaja et al., 2012). The inclusion of technology in PE, for example, also has the potential to enhance teaching and learning opportunities, while providing additional guidance to conduct assessment (Morley, van Rossum, Richardson, & Foweather, 2019; van Rossum, Foweather, Richardson, Hayes, & Morley, 2019). The National Association of Sport and Physical Education (NASPE) (2009) clearly support the potential of technology as an effective tool for enriching PE instruction. Crucially, this approach is easily transferable to the home environment as Chan et al. (2016) highlight that it is important to help children practice FMS at home, other than the school environment (Chan et al., 2016). Children see technological tools as fun, and they become more motivated in learning PE and achieving the techniques with audio visual aids (Chan et al., 2016; Grout & Long, 2009).

Instruction time (as opposed to the overall time of each session) is also an important consideration when planning interventions, although a meta-analysis conducted by Logan et al. (2012) used to determine the effectiveness of motor skill interventions in children found a non-significant relationship between the effect size of pre- to post-improvement of FMS and the duration of the intervention (in minutes). This is an unexpected finding, because it would seem intuitive that greater total intervention time would lead to a larger increase in FMS competence. The evidence, however, does not support this, and Logan et al. (2012) suggest that it is possible that children may plateau in their FMS competence after some critical amounts of instruction. The activities provided during motor skill interventions may become monotonous and lead to children disengaging over time.

The development of FMS should be one of the major aims of school PE, and this is magnified, as children and adolescents are more physically inactive than ever before (Kalaja et al., 2012; Samdal et al., 2007), while many children entering adolescence have not yet mastered basic FMS (Hardy et al., 2013). Guided by previous research (Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007), it is important to take into consideration that an intervention designed around movement skill acquisition alone would probably be insufficient to change PA behaviour in youth long term. This points to the targeting of an improvement in FMS proficiency as a strategic supplement in the promotion of PA in adolescents (Belton et al., 2014). Ultimately, it is important that researchers continue to manipulate the components of interventions, such as type of approach and amount of instruction time to determine the optimal characteristics of effective interventions (Foulkes et al., 2017). Such characteristics include the length of the intervention, the type of instructional approach and the content of curriculum (Logan et al., 2012).

A lack of proficiency in FMS may be compounded by other intrinsic risk factors such as muscle asymmetry, core stability deficiencies, and postural defects (Morton, Barton, Rice, & Morrissey, 2014). Therefore, in addition to the basic observable patterns of FMS, another indicator for actual movement skill proficiency in adolescents exists, and one which practitioners, including PE teachers, and researchers should consider. This domain of movement is known as functional movement, and is based on the assumption that strength, flexibility, mobility and stability are prerequisites that underpin movement skill performance (Kraus, Schutz, Taylor, & Doyscher, 2014). Thus, understanding or considering both fundamental and functional movement as two elements in a continuum of MC may provide a more insightful understanding within the motor development domain, by reflecting more accurately the skills and movements inherent in a wider range of sports and games in which adolescents participate (Rudd et al., 2016).

2.3 Functional Movement

2.3.1 Introduction to Functional Movement

Functional movement, defined as the ability to move the body with proper muscle and joint function (Coker, 2018), and indeed functional strength (i.e., what a person can do with their own body) are important considerations for motor development, as they are relevant to an individual's mobility and quality of life (Edelson, Mathias, Fulgoni, & Karagounis, 2016). The ability to execute different movements with correct technique should enable more effective force transmission within dynamic tasks, and aid postural stability with body alignment through open skilled activities (Lloyd et al., 2015). Within contemporary testing batteries, the assessment of neuromuscular control and kinematics are included to measure movement competencies and limitations (Portas, Parkin, Roberts, & Batterham, 2016). Periodic movement screening and proper corrections with functional training are considered very valuable to creating better movement capacities in building better physical performance (Dinc, Kilinc, Bulat, Erten, & Bayraktar, 2017). Functional movement and force-producing capabilities (strength and power) should be viewed as integral training foci within youth physical development programmes (Lloyd et al., 2015).

2.3.2 Background to the Functional Movement Screen (FMS™)

The Functional Movement Screen (FMS™) (Cook, Burton, Fields, & Kiesel, 1998; Cook, Burton, & Hoogenboom, 2006a, 2006b) is a pre-participation evaluation instrument that comprises a series of movements designed to assess the quality of fundamental movement patterns (Letafatkar, Hadadnezhad, Shojaedin, &

Mohamadi, 2014; O'Connor, Deuster, Davis, Pappas, & Knapik, 2011). The FMS™ was originally designed to assess muscle flexibility, strength imbalances and general movement proficiency in a range of performance tests; identify functional deficits related to proprioception, mobilisation and stabilisation; and determine the existence of pain during any of the prescribed movement patterns (Cook et al., 2006b; Garcia-Pinillos et al., 2019; Lloyd et al., 2015). The FMS™ may also indirectly measure intrinsic factors, such as muscular strength and activation, neuromuscular control, and core stability (Cook, 2010), all of which are generally accepted as integral to functional movement and the successful completion of the FMS™ tasks (Anderson, Neumann, & Huxel Bliven, 2015).

The FMS™ attempts to take a comprehensive approach to assess human movement and encourages clinicians to look beyond impairments and isolated single joint motion, by exploring more comprehensive movement patterns representative of those used in daily activities and sport (Wright et al., 2016). The FMS™ was developed in an effort to bridge the gap between pre-participation medical screening, and performance testing. The screening instrument offers an objective rating for control of functional movements (Fox, O'Malley, & Blake, 2014), with the varying multi-dimensional components requiring muscular strength, flexibility, range of motion (ROM), coordination, balance, and proprioception.

As consistent with the literature, the FMS™ is a robust, rapid, non-invasive, inexpensive and easily administered method of quantifying a series of basic physical movements, which can be used in athletic, as well as with the general population (Abraham, Sannasi, & Nair, 2015; Bodden, Needham, & Chockalingam, 2015; Cook et al., 2006a; Perry & Koehle, 2013; Schneiders, Davidsson, Hörman, & Sullivan, 2011). The popularity and utilization of the FMS™ has grown rapidly since its development, while its adoption at the highest level of athletics, in the military and other public service organizations has further contributed to its rise in popularity (Bonazza, Smuin, Onks, Silvis, & Dhawan, 2017).

2.3.3 Movement and Scoring Components within the FMS™

The FMS™ measures the quality of movement patterns, and motor control based on specifically determined performance criteria (Fox et al., 2014; Perry & Koehle, 2013). This screening instrument is comprised of a battery of tests to simultaneously evaluate mobility (i.e., the combination of muscle flexibility, joint ROM, and a body segment's freedom of movement) (Cook, Burton, & Fields, 2012) and stability (i.e., the ability to maintain posture and/or control motion in a static or dynamic condition) (Cook et al., 2012), including right to left asymmetries (Cook et al., 2006a), through a series of seven movements (Abraham et al., 2015).

The seven movement patterns included in the FMS™ require an interplay of muscular strength, flexibility, ROM, coordination, balance and form the basis of more complex athletic movements (Martin, Olivier, & Benjamin, 2017). It is important to note that although the tests are non sport-specific, they do challenge both upper and lower extremities, alongside the trunk in functional tasks underpinning the movements that occur during athletic performance (Abraham et al., 2015). The seven tests are identified as follows; 1) the deep squat which assesses bilateral, symmetrical, and functional mobility of the hips, knees and ankles, 2) the hurdle step which examines the body's stride mechanics during the asymmetrical pattern of a stepping motion, 3) the in-line lunge which assesses hip and trunk mobility and stability, quadriceps flexibility, and ankle and knee stability, 4) shoulder mobility which assesses bilateral shoulder ROM, scapular mobility, and thoracic spine extension, 5) the active straight leg raise which determines active hamstring and gastrocsoleus flexibility while maintaining a stable pelvis, 6) the trunk stability push-up which examines trunk stability while a symmetrical upper-extremity motion is performed, and 7) the rotary stability test which assesses multi-plane trunk stability while the upper and lower extremities are in combined motion (Kiesel et al., 2007). Three clearance tests (graded only as positive [i.e., present] or negative [i.e., absent]) are also performed to observe a pain response and offer an added insight into dysfunction by screening key areas (i.e., back and shoulder), where ROM extremes are indicators of poor mobility or stability, or both (Cook, 2010). The clearing tests assess shoulder internal rotation/flexion [shoulder mobility], end range spinal flexion [rotary stability], and end range spinal extension [trunk stability push-up] (Anderson et al., 2015).

The FMS™ has a scoring range from zero to three, with three being the maximum score per individual screening assessment, and lower scores indicating functional movement deficits (Anderson et al., 2015). Essentially, this "*primitive grading system*" [0-3] (Cook et al., 2006b, p. 132) diminishes the need for extensive testing and analysis. If the participant has pain during the assessment at any stage, a score of zero is awarded. A score of one will be given to the participant if they are unable to complete the movement. If the participant has to use a compensation to perform the movement, a score of two is awarded. To receive a score of three, the individual must perform the movement correctly without any pain, or compensation.

The seven individual scores are then summed resulting in a maximum cumulative or composite score of 21. Bilateral scores are also taken for five of the seven screening items (with the exception of the deep squat and the trunk stability push-up), and compared to show the imbalance between the right and left sides of the individual. It is important to note that having tested the right and left sides, only the lowest score is then considered for the total score (Cook, 2010).

2.3.3.1 Challenges to the Existing FMS™ Tasks and Scoring Protocol

Interestingly, some of the existing seven movement assessments from the established FMS™ have been subject to partial criticism within the field (Schneiders et al., 2011; Willigenburg & Hewett, 2017). For example, the trunk stability push-up task requires not only upper-body strength, but also reflexive core stabilization, and this task evaluates the participant's ability to sequentially fire core musculature for stabilization before extremity movement (Anderson et al., 2015). The trunk stability push-up is, therefore, an important indicator of a participant's ability to stabilize the spine in an anterior and posterior plane. It has, however, been reported that participants with existing competencies in trunk stability could not score high on this specific task, if they have insufficient arm strength to perform a push-up (i.e., when their thumbs are aligned to the top of their forehead or chin) (Willigenburg & Hewett, 2017). With this viewpoint, it can be argued that the push-up is an assessment of muscular strength for the young adolescent, as opposed to an assessment of stability (Portas et al., 2016). Furthermore, the rotary stability assessment has been suggested to be removed from subsequent versions of the FMS™ due to its difficult, non-diagnostic nature (Schneiders et al., 2011). Specifically, the rotary stability assessment places the participant under controlled conditions where careful, controlled movements are encouraged, unlike the transferable explosive, multi-directional components of sports, such as Gaelic Games (Fox et al., 2014).

The FMS™ has benefits in recognising deficiency in certain movements, and with further training, the performance of these particular movements can improve (Bardenett et al., 2015). The ability of the FMS™, therefore, to detect abnormal movement patterns can be useful when planning training programmes (Onate et al., 2012). Interestingly, a study on 1163 junior male soccer players (age range: 8–18 years old) from nineteen English Football League clubs separated the FMS™ into 3 parts, specifically three movement tests (deep squat, hurdle step, in-line lunge); two mobility tests (shoulder mobility, active straight leg raise) and two stability tests (trunk stability push-up, rotary stability) to enable a deeper understanding of the FMS™ composite score (Portas et al., 2016). This practice has been repeated in other recent research involving youth elite male soccer players (N = 65; mean age: 15.89 ± 0.53 years) representing four professional clubs in Italy (Campa, Spiga, & Toselli, 2019). The ability of practitioners to tailor interventions according to the individual's needs is somewhat limited however by the existing scoring system of the FMS™.

A recent review by Bonazza et al., (2017) which analysed the structure of the FMS™ have questioned the ambiguity inherent in the grading structure and the sensitivity in identifying functionally relevant movement limitations (Beach, Frost, & Callaghan, 2014; Beach, Frost, McGill, & Callaghan, 2014; Clifton, Harrison, Hertel, & Hart, 2013; Frost, Beach, Callaghan, & McGill, 2012, 2015; Whiteside et al., 2016). Recent studies of the FMS™ suggest that the use of a single FMS™ composite score may be flawed, given that each individual test is relatively independent in its own unique construct (Li, Wang, Chen, & Dai, 2015; Wright et al., 2016). The different FMS™ tasks have been challenged from the perspective that they do not appear to represent unitary constructs, which brings the use of the summed total overall score into question (Kazman, Galecki, Lisman, Deuster, & O'Connor, 2014; Willigenburg & Hewett, 2017). Furthermore, the difficulty in assessing and performing the more complex tests involving multiple joints, and complex physical qualities such as balance, coordination (for example, the in-line lunge) and core stability make FMS™ scoring and performance uncertain (Bakken et al., 2017). Findings from a number of studies have established that a large number of participants score 2 on particular FMS™ tasks (Bodden et al., 2015; Frost et al., 2012), however, the awarded score of 2 encompasses a broad range of movement qualities and differences between participants (i.e., good 2's and bad 2's) (Bodden et al., 2015).

It may be beneficial to incorporate more precision in the FMS™ scoring criteria to capture a greater amount of information from the existing movement assessment tool. One of the overall limiting factors of the FMS™ in the literature is that the tool serves only as a filter to detect large limitations of functional movement (Butler, Plisky, & Kiesel, 2012). By increasing the precision of the FMS™, specifically by itemizing the scoring of each subtest, may result in greater sensitivity for identifying changes in whole-body function, detecting injury risk and responding to intervention (Butler et al., 2012; Waldron, Gray, Worsfold, & Twist, 2016). As a point of comparison to the Cook et al., (2006a) protocol, the 100-point FMS™

scoring system was developed by Butler et al. (2012), whereby the individual seven movement tasks were assigned additional weighted scoring criteria. Instead of assigning a single score to the movement task, as with the existing composite scoring protocol, scores in the Butler et al., (2012) scale are given weighting for each task criterion and then summed to reach a task score (Anderson et al., 2015). The goal of the 100-point FMS™ is to provide practitioners and researchers with additional information to improve the predictive value of the FMS™. This research addition has been achieved by improving measurement precision through the itemized scoring of the subtests, and by identifying specific deficits within the whole movement pattern (Anderson et al., 2015; Butler et al., 2012). This 100-point scoring alternative may be helpful in targeting intervention techniques and strategies towards specific movement pattern components, as opposed to focusing on the entire holistic movement strategy (Butler et al., 2012).

2.3.4 Asymmetries and Compensatory Movement Identification within the FMS™

Research suggests that muscle weaknesses and imbalances, as well as any accompanying mobility and stability problems may cause a participant to develop compensatory or suboptimal movement patterns (for example, a basketball player landing in a knee valgus position), which results in poor biomechanics, performance decrements and an increased potential risk of injury (Cook, 2010; Cook et al., 2006a; Dossa, Cashman, Howitt, West, & Murray, 2014; Heijne, Flodström, & von Rosen, 2019; Wieczorkowski, 2010). The FMS™, as an assessment instrument, is therefore intended to evaluate deficiencies in the mobility and stability of a participant that might be linked to injury (Abraham et al., 2015). Furthermore, the FMS™ is designed to identify potential limitations or asymmetries in healthy individuals, with respect to basic movement patterns. Functional asymmetries are defined as side-to-side differences in kinetics and kinematics during performance of otherwise symmetrical tasks, and measurable levels of functional asymmetries have been found to be commonplace in healthy populations (Overmoyer & Reiser II, 2013). Chorba, Chorba, Bouillon, Overmyer, and Landis (2010), for example, found that compensatory fundamental movement patterns in female collegiate athletes can be identified by using the FMS™. Asymmetries, including mobility, ROM and strength differences between sides, have been identified as possible injury-related risk factors (Bardenett et al., 2015; Knapik, Bauman, Jones, Harris, & Vaughan, 1991; Nadler et al., 2001; Plisky, Rauh, Kaminski, & Underwood, 2006; Shanley et al., 2011), albeit functional asymmetries do not necessarily reflect strength asymmetries, or vice versa (Willigenburg & Hewett, 2017).

According to Cook et al. (2006a, 2006b), the FMS™ instrument was designed to challenge the interactions of kinetic chain mobility and stability, necessary for performance of fundamental and functional movement patterns. The basis for use of the FMS™, as proposed by Cook et al. (2006a, 2006b), is that repetitive microtrauma can be caused by an adoption of inefficient movement strategies, when performing basic physical movements, which may predispose individuals to musculoskeletal injury (Chorba et al., 2010). Individuals, including athletes, often utilise compensatory movement strategies in order to achieve high levels of performance, but in doing so, reinforce and habitualise poor movement patterns (Chorba et al., 2010). Similarly, studies have demonstrated that children progress through developmental sequences starting with movements that are inefficient and have little functional utility, and progress to more mechanically efficient movements that can be successfully applied in sports and games (Bardid, Huyben, et al., 2016; Gallahue et al., 2012). In summary, the FMS™ strives to increase movement efficiency by emphasising the efficiency of movement patterns, rather than the quantity of repetitions performed (Perry & Koehle, 2013).

2.3.5 Reliability and Validity of the FMS™

The FMS™ requires minimal training to administer, and can be conducted using multiple raters with varying experience (Bonazza et al., 2017; McMullen, 2013). In addition, reliable scoring data can be achieved, regardless of the rater's training in the FMS™ (Onate et al., 2012; Smith, Chimera, Wright, & Warren, 2013; Teyhen et al., 2012).

Intrarater reliability is important because it shows that a single rater or clinician can provide consistent scoring results over repeated administrations (i.e., multiple trials) of the FMS™ (Stobierski, Fayson, Minthorn, Valovich McLeod, & Welch, 2015). Interrater reliability is important because it shows that multiple raters scoring the same test (i.e., single trial) can report consistent results (Onate et al., 2012; Smith et al., 2013; Stobierski et al., 2015; Teyhen et al., 2012). The reliability of the FMS™ has been examined extensively by previous research, albeit primarily with adult populations, and has been reported to have strong inter and intrarater reliability (Butler et al., 2012; Gribble, Brigle, Pietrosimone, Pfile, & Webster, 2013; Minick et al., 2010; Onate et al., 2012; Smith et al., 2013; Teyhen et al., 2012), adding to its clinical usefulness (Fox et al., 2014). At the component level of the FMS™, the hurdle step has been shown to show the lowest agreement in existing reliability studies (Onate et al., 2012; Smith et al., 2013), whereas the shoulder mobility (Smith et al., 2013) and rotary stability (Onate et al., 2012) assessments have shown the greatest agreement (Fox et al., 2014). A recent systematic review and meta-analysis by Bonazza et al. (2017) found that the in-line lunge, rotary stability, and hurdle step were all identified as the least reliable assessments (Minick et al., 2010; Onate et al., 2012; Parenteau-G et al., 2014; Schneiders et al., 2011; Teyhen et al., 2012; Wright, Portas, Evans, & Weston, 2015).

Studies suggest that the FMS™ may be used confidently across varying levels of experience to identify musculoskeletal deficits in athletes (Fox et al., 2014). Both Shultz, Anderson, Matheson, Marcello, and Besier (2013) and Gulgin and Hoogenboom (2014) found that the overall scores in the FMS™ did not differ significantly between raters of different experience levels (Gulgin & Hoogenboom, 2014; Shultz et al., 2013). Following a review of three studies which assessed the rater reliability of the FMS™ scoring process in real time, Stobierski et al. (2015) found that regardless of the level of expertise in scoring the FMS™ (for example, minimal training, FMS™ certified), clinicians can demonstrate good to excellent intrarater (ICC = .74–.92) and interrater (ICC = .76–.98) reliability (Onate et al., 2012; Smith et al., 2013; Teyhen et al., 2012). These findings indicate that clinicians' ability to score the FMS™ is consistent regardless of the number of raters, or the level of FMS™ training which the raters have had (Onate et al., 2012; Smith et al., 2013; Teyhen et al., 2012). By concluding that the interrater reliability between a novice and experienced rater resulted in high agreement (ICC = .81–.91), Smith et al. (2013) showed that functional movement data could be consistently scored on a sample of 20 healthy, injury-free, and physically active men (n = 10) and women (n = 10) (median age range: 22–41) by field testers (with varying degrees of FMS™ experience) after a 2-hour structured training session. Furthermore, it is interesting to note that intrarater reliability was not increased through FMS™ certification within this study (Smith et al., 2013).

Overall, there is significant evidence that the composite scores for the FMS™ are reliable and can be replicated by raters with varying degrees of experience (Bonazza et al., 2017). Based on the results of a systematic review and meta-analysis, the FMS™ as a composite score has excellent interrater and intrarater reliability (Bonazza et al., 2017). These findings also suggest that the level of experience and formal certification have little effect on scoring for the FMS™ (Bonazza et al., 2017).

While the FMS™ has excellent interrater and intrarater reliability (Minick et al., 2010; O'Connor et al., 2011; Smith et al., 2013), according to Bonazza et al. (2017), significant concerns remain regarding the validity of the FMS™. Although it is essential to have a highly repeatable test as a first step to establishing validity, this is not a sufficient condition alone for a valid measurement tool (Gribble et al., 2013; Kazman et al., 2014; Shultz et al., 2013). Studies for validity have in fact demonstrated flaws in both internal and external validity of the FMS™ (Bonazza et al., 2017). Furthermore, because of the absence of any gold-standard comparison, the significant heterogeneity of the existing data, alongside the insufficient evidence as a whole, it is difficult to derive any definitive conclusions from the current literature as to whether the FMS™ is a valid tool for the measurement of functional limitations and asymmetries, which highlights the need for further evaluation of the FMS™

(Bonazza et al., 2017; Philp et al., 2018). Bonazza et al. (2017) did, however, conclude in their systematic review and meta-analysis that the FMS™ lacks validation of its structure as a composite score of multiple subtest scores, and of its ability to accurately and sensitively measure deficits in posture and balance.

The literature to date has predominantly sought to validate the FMS™ for prediction of injury among active populations. Based on analysis of the current literature, including systematic reviews and meta-analyses (Bonazza et al., 2017; Dorrel, Long, Shaffer, & Myer, 2015; Philp et al., 2018), findings have varied support in regard to the predictive validity of the FMS™ for injury across multiple active adult populations, as well as the validity of the FMS™ as a screening test (Bonazza et al., 2017; Chorba et al., 2010; Dorrel et al., 2015; Dossa et al., 2014; Frost et al., 2012, 2015; Kazman et al., 2014; Philp et al., 2018; Smith et al., 2013; Warren, Smith, & Chimera, 2015; Whiteside et al., 2016). A study by Kazman et al. (2014), for example, on 934 Marine officer candidates (94% male; mean age: 22.4 ± 2.7 years; age range: 18–34) concluded that due to the low internal consistency, each movement should be considered separately, and the FMS™ total score is not valid as a unidimensional construct. Thus, they suggested that the summary score for the FMS™ is likely not a valid tool (clinically and statistically) and specific movements should be addressed individually. Interestingly, they suggested that additional research should examine the construct validity and factor structure of the FMS™, and focus more on item development and score validation and less on applying the FMS™ to predict injury (Kazman et al., 2014). Future research is also needed to further validate an association between age and FMS™ scores in younger populations (Bardenett et al., 2015).

2.3.6 Background to Examining the FMS™ in Children and Adolescents

Adolescents have unique biological ages (Malina, Bouchard, & Bar-Or, 2004) and research has identified maturation as an influencing factor on FMS™ scores (Lloyd et al., 2015). Essentially, this population experience skeletal, neuroendocrine (i.e., interactions between the nervous and endocrine systems, especially in relation to hormones) and sexual maturation developments that make the assessment of physical performance and training prescription of young athletes a complex process (Malina et al., 2004; Portas et al., 2016). Both Paskewizc et al. (2013) and Perry and Koehle (2013) identified differences in FMS™ scores across age and maturation ranges (Paszkewicz, McCarty, & van Lunen, 2013; Perry & Koehle, 2013). This suggests that functional movement patterns are dynamic and may be influenced by age and maturation, in addition to intrinsic factors such as muscle activation, neuromuscular control, and mobility (Anderson et al., 2015). The rapid increases in body dimensions, limb length and the significant development of muscle mass, associated with maturation indicate that the determination of movement proficiency during this stage of development may be affected as adolescents learn to move with fluctuating levels of coordination (Lloyd et al., 2015; Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, 2012).

The generalisability of the FMS™ across different age populations may not be appropriate (Anderson et al., 2015) as childhood and adolescence reflects a period of non-linear development (Malina et al., 2004), with periods of little fluctuation followed by periods of rapid change, characterised by a general plateau in performance and no improvement in FMS™ scores (Lloyd et al., 2015). It could be suggested that the plateau in performance may represent a period of ‘adolescent awkwardness', which is a term used to reflect a temporary disruption in motor control performance associated with this stage of development (Beunen & Malina, 1988; Lloyd et al., 2015; Philippaerts et al., 2006; Quatman-Yates et al., 2012). In a recent study on 1163 male English Football League soccer players (age: 8–18 years) there was a substantial increase (10%) in those able to achieve a score of ≥14 on the FMS™, specifically for those who were at post-peak height velocity (PHV) compared to pre-PHV, which confirms that PHV and maturity have substantial effects on FMS™ performance (Portas et al., 2016).

In 2015, Abraham et al. (2015) carried out a study (N = 1005) to establish normative values for the FMS™ in adolescent school aged children (10 to 17 years) in India. Prior to this publication, the authors highlighted that there were no published normative values for the FMS™ in an adolescent school aged population. As such, the clinical utility of FMS™ is limited by its lack of normative reference values in the child and adolescent population. Furthermore, the absence of any study, specifically to establish cut off scores in the adolescent population, has limited the clinical utility of the FMS™. Schneiders et al. (2011) has, however, previously established normative values for the FMS™ in young active individuals (N = 209; mean age: 21.9 ± 3.7 years). Abraham et al.'s (2015) study provides normative values for the FMS™ in adolescent school aged children, assisting global data on functional mobility, and stability within this population.

2.3.7 FMS™ Levels by Gender in Children and Adolescents

Anderson et al. (2015) highlighted that sex differences in balance, core stability, and neuromuscular control are well documented in the literature. Evidence-based findings suggest that females have decreased muscle activity in the gluteus medius (Hart, Garrison, Kerrigan, Palmieri-Smith, & Ingersoll, 2007), vastus medialis oblique and vastus lateralis (Kim, Yoo, & Yi, 2009), decreased neuromuscular control (Brophy et al., 2009; Hughes, Watkins, & Owen, 2008; Kernozek, Torry, & Iwasaki, 2008; McLean, Lipfert, & van den Borgert, 2004), and core stability (Brophy et al., 2009; Evans, Refshauge, & Adams, 2007; Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007), when compared to males (Anderson et al., 2015). Although conflicting evidence regarding the effect of gender on total mean FMS™ scores exist, lower total FMS™ scores have been reported for female secondary school youth (Anderson et al., 2015) and female adolescent (Abraham et al., 2015) athletes, when compared to males of the same age (Martin et al., 2017).

The Abraham et al. (2015) study was the first of its kind to provide comprehensive descriptive data on participants using a large sample size, on an adolescent aged school population (10 to 17 years). This study further investigated whether the performance differed between gender, and between those with, or without previous history of injury. Results from this study revealed that significant differences were apparent between gender on four of the individual FMS™ tests. Males displayed higher efficiency in the in-line lunge, active straight leg raise, trunk stability push-up, and the rotary stability assessments, when compared to females. There were also significant differences observed in the composite overall FMS™ scores between gender. Similarly, the Anderson et al. (2015) study was also one of the first studies to identify differences in composite FMS™ scores, as well as differences in individual FMS™ task scores between healthy male and female secondary school athletes. Healthy secondary school female athletes scored lower on the total composite ($p = 0.004$) than healthy secondary school male athletes. Females also scored lower on the following individual FMS™ tasks: in-line lunge ($p = 0.04$) and trunk stability push-up ($p = 0.001$) (Anderson et al., 2015).

More recently O'Brien et al. (2018) gathered conflicting cross-sectional FMS™ data on a general sample of school-based adolescent youth (N = 219; mean age: 14.45 ± 0.96 years). Significant gender differences emerged in FMS™ composite score, with females ($p = .01$) interestingly performing better than males. When broken down by specific screening items, females displayed significantly higher functional movement proficiency in the active straight leg raise ($p = .001$), and the shoulder mobility ($p = .01$) test, while males displayed significantly higher functional movement proficiency in the trunk stability push-up test ($p = .001$) (O'Brien et al., 2018). Supporting O'Brien et al., (2018), Schneiders et al. (2011) found significant differences between female [higher efficiency on the active straight leg raise and the shoulder mobility tests] and male [higher efficiency on the trunk stability push-up and the rotary stability tests] participants on four individual FMS™ tests. However, unlike Abraham et al. (2015), Anderson et al. (2015) and O'Brien et al. (2018), there were no significant differences for composite overall FMS™ scores between females and males in the Schneiders et al., (2011) research, indicating that the FMS™ can be used to compare individuals in mixed populations. This is an important finding because the majority of published research on the FMS™ has been conducted either exclusively or predominantly on males. Perry and Koehle (2013) note that there is only one difference between the FMS™ protocol for males and females: an adjusted hand placement during the trunk stability push-up assessment for the female's assessment. The movements are based on one's ability to elicit a functional movement, rather than recruitment of muscles to produce force, and this enables males and females to perform the movements reasonably equally (Perry & Koehle, 2013).

2.3.8 FMS™ Injury Detection in Youth Populations

Factors that may contribute to the increased injury risk of youth include deficits in mobility, core stabilisation, and uncoordinated movement patterns (Anderson et al., 2015). The FMS™ was designed to predict non-contact injuries as movement patterns are independent of contact (Martin et al., 2017). To achieve a required task through normal movement, an integration of fundamental movement patterns with an appropriate mobility-stability balance is required (Cook et al., 2006b). In response to pain, weakness, tightness, or structural abnormality, the human system adapts predictable protective movement patterns (Kiesel, Plisky, & Voight, 2007). Eventually, these adapted movement patterns result in decreased ROM, muscle length changes, and compromised strength over time (Martin et al., 2017).

Recent research by Bardenett et al. (2015) sought to determine if the FMS™ is a valid predictor of injury within a high school athletic population, and to identify a potential new FMS™ cut-off score for this population. One hundred and sixty-seven high school athletes from several sporting backgrounds (90 females; 77 males; aged 13 to 18 years) from one public high school were assessed using the FMS™, and were monitored for injury during a single season. According to the results of this study, the FMS™ is not a valid predictor of injury in high school age athletes.

Furthermore, the authors are unable to propose a cut-off score for high school athletes, as the receiver operating characteristic (ROC) curve indicated that there is no cut-off point that might be considered predictive of injury. Martin et al. (2017) also determined that the total FMS™ score is a poor predictor of non-contact injuries among high school cricket pace bowlers.

In contrast to much research (Bonazza et al., 2017; Chorba et al., 2010; Kiesel et al., 2007; O'Connor et al., 2011), these findings with high school athletic populations seem to dispel the 'traditional' FMS™ score of <14 for injury detection. In the Abraham et al. (2015) study, for example, 46.5% of the participants had a score of 14 or less, which if following globally accepted scoring protocol (Duke, Martin, & Gaul, 2017; Garrison, Westrick, Johnson, & Benenson, 2015; Lisman, O'Connor, Deuster, & Knapik, 2013) might indicate a potentially higher risk of injury to those participants. It is, however, possible that younger participants present varying levels of maturity, development and motor control, and the traditionally accepted FMS™ scores may not be appropriate for detecting those at injury risk in young populations. Although a recent review concluded that there is only moderate evidence for a relation between FMS™ score and injury risk (Kraus et al., 2014), future research is needed to further validate an injury-related association between age and FMS™ scores in younger populations (Bardenett et al., 2015).

2.3.9 Functional Movement Interventions

It is recognised in the literature that functional movement, as measured by the FMS™, can be improved through structured intervention implementation (Kiesel, Plisky, & Butler, 2009). By assessing functional movement patterns with the

FMS™, clinicians may be able to detect deficiencies in functional capacity and thus create individualised exercise programmes that focus on improving specific movement patterns to restore optimal functional movement (Huxel Bliven & Anderson, 2013). Research also suggests that the development of specifically tailored interventions, based on FMS™ scores, could potentially decrease the likelihood of injury, and overall time missed from physical activities (Stobierski et al., 2015). For example, international based research, particularly with high school students in the USA (Dexter, Renggli, May, & Larkins, 2020; Sorenson, 2009; Wieczorkowski, 2010), suggests that a proactive, functional training approach can enhance overall wellness and productivity in active populations.

Corrective exercises have been developed globally to retrain measureable dysfunctional movement patterns, establish symmetrical movement, and improve balance posture (Cook, 2010). Specific corrective exercises can be targeted to remediate faulty movement patterns (Butler et al., 2012). These corrective exercises stimulate natural core muscle activation to enhance the relationship between core muscle function and fundamental movement (Cook & Fields, 1997).

Researchers have consistent evidence showing that individuals who don't have adequate FMS™ scores can improve and develop their dysfunctional movement patterns with corrective exercise programmes (Cook et al., 2006b; Dinc et al., 2017; Letafatkar et al., 2014). The results of an eight week intervention programme on 25 male mixed martial arts (MMA) athletes competing at a semi-professional level (mean age: 24.31 ± 4.46 years) determined that FMS™ scores significantly improved providing the opportunity to adapt or implement new additions to training programmes, while building in exercise progressions (Bodden et al., 2015). The corrective intervention, required these athletes to complete a corrective exercise programme four times per week using prescribed exercise selection guides, as recommended in the FMS™ advanced corrective exercise manual (Cook et al., 2012), based on the dysfunctions and limiting factors identified using the FMS™ (Bodden et al., 2015). Interestingly, a recent study by Yildiz et al. (2019) on 28 young tennis players (mean age: 9.6 ± 0.7 years) involved a training programme implemented on three non-consecutive days each week, also for eight weeks, and found a positive effect of functional training exercises on athletic performance and functional movement between the fourth and eighth weeks (Yildiz et al., 2019).

In the USA, a randomized controlled trial was used by St. Laurent, Masteller and Sirard (2018) to assess the efficacy of a suspension-training movement programme to improve functional movement in children ranging from 7 to 12 years of age (N = 28; male: 46%; mean age: 9.3 ± 1.5 years). The intervention group (n = 17) participated in a 6-week suspension-training movement programme, which used a series of bodyweight suspension trainer exercises for two 1-hour sessions per week. All participants started with the most basic level of each movement and were given individual progressions or encouraged to progress to a more challenging version of that movement, as appropriate. The control group (n = 11) continued participation in regular activities, which included their regular athletic practices and events, and were not exposed to the intervention programme. Acknowledging the small sample size, the intervention group demonstrated a 28.9% improvement in the total FMS™ score at follow-up (an average increase in score of 4.06), when controlling for baseline ($p \leq .01$). Conversely, the control group experienced a 7.1% decrease in FMS™ score (an average decrease in score of 0.91). While a full data set of individual FMS™ task scores were not reported, the intervention group had significantly greater improvement in all individual movements of the FMS™ (mean improvement on each task from 0.53 to 0.76 with SDs ranging from 0.51 to 0.75), with the exception of the shoulder mobility assessment (St. Laurent et al., 2018).

In China, Liao et al. (2019) evaluated the effect of a twelve week intervention of functional strength training (FST) on movement quality among 12- to 13-year-old untrained middle school girls. Participants (N = 144; mean age 12.47 ± 0.57 years) were randomly assigned to either the FST group or a traditional strength training (TST) group. The FST group underwent ten functional movement corrective exercises in the first six weeks and ten functional strength promotion exercises in the following six weeks, whereas the TST group did ten TST exercises with progressive intensity over the twelve week period. The training consisted of 45 minute sessions and took place three times per week for both groups during regular PE classes (i.e., 36 sessions in total). A group-by-time interaction effect on the total FMS™ score showed the FST group had significant improvements overall when compared with the TST group, as well as in specific tests including the deep squat and the trunk stability push-up. Findings indicate that a FST programme may be more effective at improving movement quality and related areas of muscular strength, flexibility, and power among a cohort of middle school girls, and may result in better health promotion and injury prevention than a TST programme (Liao, Li, & Wang, 2019).

In the United Kingdom, Wright et al. (2015) previously investigated the effects of a four week, school-based, lunch time intervention on FMS™. Participants included twenty-two secondary school individuals (N = 22; age: 13.4 ± 0.9 years; range: 11.8 to 15.2 years; height: 162.0 ± 7.8 cm; weight: 51.2 ± 9.5 kg). The intervention group (n = 11) received four 30-minute weekly training sessions, with an emphasis on movement quality, consisting of 9 exercises using body weight or resistance bands. These exercises included; crawling; pike walk; glute activation; squatting; lunging; prone plank; push-ups; upper body pull and; dynamic landing. Each exercise could be progressed through varying levels of difficulty, while participants progressed by consistently performing the exercise correctly. Approximately 3 minutes was assigned to each exercise, and the time was divided into activity, coaching, and feedback on an individual basis. The control group (n = 11) was engaged in multisport activities that replicated the PE curriculum, focusing on generic sport or game skills, rather than the underlying movements. When compared with the control, the intervention made little impact on the total FMS™ score (i.e., a likely trivial effect was observed on the total FMS™ score). This is based on the adjusted change scores with 1 arbitrary unit, as proposed by Wright et al. (2015), being the smallest worthwhile effect or clinically relevant change in FMS™ score. Core stability, assessed by the plank test, did improve however, indicating that short-term interventions might affect specific isolated components of fitness but not overall FMS™ performance. According to Wright et al. (2015), these findings raise questions about the ability of the FMS to detect subtle changes in movement over time, particularly in adolescent populations.

Recently, Coker (2018) examined whether functional movement proficiency, as measured via the FMS™, could be improved using a standardized warm-up protocol over the course of a six week period in middle school PE. Participants (N = 120; 45% male; mean age: 13.18 ± 0.39 years) from 7th- and 8th-grades were randomly assigned to a functional group (n = 54) and a control group (n = 66). For six weeks, the functional group warmed up by performing functional stretching, stability, and mobility exercises while the control group completed a traditional dynamic warm-up. Results showed that those in the functional group significantly reduced dysfunctional movements (i.e., scores of 1) compared with those in the control group. Furthermore, boys in the functional group significantly improved their FMS™ composite score compared with their male counterparts in the control group whose scores declined. The findings suggest that a warm-up that targets typical physical development challenges of middle school-aged youth, namely, ankle mobility, pelvic stability (quadriceps dominance), and inactive and/or weak gluteal muscles, abductors, and adductors, implemented over the course of six weeks can significantly reduce functional deficiencies compared with a traditional dynamic warm-up. Replacing the traditional dynamic warm-up with one that emphasizes functional movement in preparation for activity in PE appears effective for correcting movement dysfunctions in young adolescents (Coker, 2018).

Following the development of a FMS™ intervention, the potential then lies in an individual’s ability to oversee corrective exercise as this can vary significantly from person to person (Bodden et al., 2015). In relation to the identification of a sports specific adaptation, Bodden et al., (2015) also questions the assumption that correcting dysfunctional movement patterns may potentially affect an individual’s sporting performance. Finally, it must be acknowledged that the assessment of functional movement in children and adolescence is still a relatively new area of research (St. Laurent et al., 2018); with many of the studies to date being observational in nature (Abraham et al., 2015; Anderson et al., 2015; Duncan, Stanley, & Leddington Wright, 2013; Mitchell, Johnson, & Adamson, 2015). That said, the critical analysis and interpretation of prior intervention research in this area, such as those studies identified in this section, provide a strong rationale and justification for the inclusion of functional movement as a measure of MC in youth populations.

2.3.10 Future Directions of the FMS™ in Youth Populations

Although normative values in physically active adolescent school-aged populations have now been reported (Abraham et al., 2015), the FMS™ has not yet been validated for use in high school athletes. It is therefore imperative that prior to testing, subjects are familiarized with the FMS™ and study protocol, and examiners utilize the same verbal instructions provided by Cook et al. during testing (Bardenett et al., 2015). As with Abraham et al.'s (2015) study, the test administration procedures, instructions and scoring process associated with the standardized version of the test must be followed in order to ensure accuracy in scoring.

According to Abraham et al. (2015), future research should target a specific sporting population in the adolescent school-aged population, and should look for improvement in FMS™ scores following an intervention within these sporting groups. Lloyd et al. (2015) demonstrated that selected tests (in-line lunge, deep overhead squat, active straight leg raise and rotary stability) within the FMS™

battery were significantly correlated to three measures of physical performance (squat jump height, reactive strength index and reactive agility), explaining a portion of the variation in athletic performance in youth soccer players in this study. These may be the most useful tests from within the FMS™ battery to predict physical performance (Lloyd et al., 2015) and future research warrants further investigation into the relationship between selected tests and physical performance in specific populations.

While the FMS™ is a reliable screening instrument, further research is needed to better understand how to best use this instrument, particularly within a school setting, beyond an athletic population. Future studies should focus on collecting FMS™ scores over a longer period of time, specifically to assess if changes in movement patterns can be detected. Primary areas for future research include determining if functional movement changes occur over time through intervention, or as a result of the biological process of maturation (Stobierski et al., 2015). Furthermore, future studies should try to validate the use of the FMS™ in adolescent school-aged population, by establishing a cut-off score for predicting injury rate and performance in the said population (Abraham et al., 2015). Additional research is also warranted to examine gender differences at different age and maturation levels, to identify correlations between movement capacity as measured by the FMS™, and various intrinsic risk factors, and to determine whether specific intervention programmes based on these factors are needed to successfully improve movement capacity (Anderson et al., 2015). Bardenett et al. (2015) suggest that other additional research in the future compare FMS™ in fatigued to non-fatigued athletes, as multiple sources indicate a loss of motor control in a fatigued state (Forestier & Nougier, 1998; Lees, 2003; Mathers & Grealy, 2014; McLean & Samorezov, 2009).

Research by Butler et al. (2012) has indicated that it is helpful to score the individual components of the movement so that interventions can be targeted towards specific movement areas. This breakdown of the movement pattern will allow future studies to assess how specific interventions can promote optimal total body movement patterns (Butler et al., 2012). Ultimately, identifying individuals with an insufficient movement foundation (Bodden et al., 2015), as well as any weaknesses and asymmetries, by intervening to improve in these areas could play a key role in enabling lifelong habitual PA participation and movement (Perry & Koehle, 2013) for children and adolescent youth.

2.4 Intervention Components

The purpose of this section is to provide a brief overview of the evidence surrounding different intervention components, specifically in relation to i) classroom-based PA, ii) digital technology integration and, iii) perceived motor competence (PMC).

2.4.1 Classroom-Based Physical Activity

In the context of comprehensive and coordinated approaches to school health, academic classrooms have gained attention as a promising setting for increasing PA and reducing sedentary time (Webster, Russ, Vazou, Goh, & Erwin, 2015). Irrespective of the terminology used – active lessons, activity breaks or activity bursts, brain breaks, energizers, or indeed movement breaks – the shared philosophy behind these PA breaks is to provide an interruption to the prolonged sedentary behaviours common in the school day (McMullen, Kulinna, & Cothran, 2014).

Several programmes such as Active Smarter Kids (Resaland et al., 2018), Bizzy Break! (Murtagh, Mulvihill, & Markey, 2013), Physical Education and Physical Literacy (PEPL) approach (Telford, Olive, Keegan, Keegan, & Telford, 2021), Physical Activity Across the Curriculum (Donnelly & Lambourne, 2011), Project Energize (Mahar et al., 2006), Project Spraoi (Bolger et al., 2019), Take 10 (Kibbe et al., 2011) and Texas I-CAN (Bartholomew & Jowers, 2011; Grieco, Jowers, Errisuriz, & Bartholomew, 2016), have introduced PA into the school learning environment in the primary school domain (Dyrstad, Kvalø, Alstveit, & Skage, 2018), with encouraging findings emerging in relation to PA (Kibbe et al., 2011; Mahar et al., 2006; Murtagh et al., 2013), PL (Telford et al., 2021), as well as other areas such as academic achievement (Centeio et al., 2018; Kibbe et al., 2011; Resaland et al., 2018). The study by Murtagh et al., (2013), for example, involved three Irish primary schools and indicated that a daily 10 minute classroom-based activity break (Bizzy Break!) implemented for a duration of just five days had a significant effect on the in-school PA levels of children. This is encouraging as the intervention required no special skills or facilities, was implemented in limited space in classrooms and teachers received no training (Murtagh et al., 2013).

In the USA, Turner and Chaloupka (2017) used nationally representative survey data from 640 public elementary schools to assess the extent to which PA is integrated into the classroom. Findings suggested that the integration of PA into the classroom – either through brief activity breaks (used in 75.6% of schools), lessons that incorporate movement into instruction as active lessons (used in 71.7% of schools), or a combination of both – only occurs in about three out of four elementary schools. However, the authors also acknowledge that this is an optimistic estimate of the extent of these practices, not only because of the potential for desirability bias in survey responses, but because many of the schools that reported the use of these practices do not have full implementation among all – or even most – of their teachers, while activity breaks are not used frequently enough to provide students with sufficient movement opportunities on a regular basis (Turner & Chaloupka, 2017).

While this type of approach may not be embraced by all classroom teachers, many teachers are willing and capable of integrating PA breaks within their lessons while there is growing knowledge and indeed acceptance of the fact that all staff have an important role to play in the promotion of PA in the school setting (Hills, Dengel, & Lubans, 2015). McMullen et al., (2014) sought to explore classroom teachers' perceptions of incorporating PA breaks into their classroom and to determine specific features of preferred activity breaks. Twelve elementary and high school classroom teachers from one Indigenous school district participated in the study and emergent themes included; the need for and threats to classroom control; a preference for breaks with connections to academic content; and the importance of implementation ease and student enjoyment. The findings indicated that teachers prefer activity breaks that are easy to manage, quick, academically oriented and enjoyable for students (McMullen et al., 2014). These findings not only have practical implications when considering PE teacher education and continuing professional development (CPD) that targets classroom teachers (McMullen et al., 2014), but equally so when planning intervention strategies as well as whole-school approaches to health.

Research has shown that there may be an inherent need to transcend the subject of PE further within the broader school environment, specifically to prepare youth for a lifetime of PA engagement (Belton et al., 2014). This reflects a move away from the traditional viewpoint of the PE teacher being the person in the school with sole responsibility for health promotion and instead typifies the development of a collaborative whole-school approach (McMullen et al. 2015; NCCA 2017). This shift in cultural focus is similar to other whole-school approaches targeting numeracy and literacy, whereby the sole responsibility no longer resides with the Mathematics and English teacher respectively (Department of Education and Skills 2011). Sustainable strategies must be identified and pursued to secure the successful assimilation of movement integration into routine practices, and a guarantee that student health receives the attention it needs throughout each and every school day (Webster et al., 2015).

2.4.2 Digital Technology Integration

The deployment of digital technology to support teaching and learning has grown exponentially in recent years (Casey, Goodyear, & Armour, 2017). Digital technology crosses multiple sectors (e.g., education, journalism, sport), multiple contexts (e.g., home and school), and can be used in multiple ways (e.g., improve learner–learner interaction or personalised learning) (Casey et al., 2017). Digital devices, applications and social media sites are readily accessible and are used by many young people on a daily basis (Casey et al., 2017; Greenhow & Lewin, 2016). However, despite increasing availability of digital technology, questions still remain amongst practitioners and researchers as to how we gain maximum benefit from the array of technology at our disposal (Wintle, 2019). While interest and research in technology's role in education has grown, its role and widespread adoption in PE remains in question (Wyant & Baek, 2018).

The inclusion of technology within the PE environment has the potential to promote effective teaching and learning (Chan et al., 2016; Marttinen, Landi, Fredrick, & Silverman, 2020). The integration of technology as part of the instructional processes also has the potential to provide a platform for further self-regulated practice, and learning outside of the school context by allowing students to make improvements independently. Research has confirmed that helping children practice FMS, for example, at home, outside of the school environment is important (Chan et al., 2016).

Interestingly, Goodyear and Armour (2018) claimed that despite limited evidence, there is a tendency in both research and policy to either take an overtly positive or overtly negative stance toward digital technology. In a recent study by Marttinen et al., (2020), it was found that teachers were willing to integrate wearable digital technologies (i.e., accelerometers, for example), if they augmented (and did not replace) their preferred purpose of PE. Given this, ideologies of teachers influenced the role that technologies played in teaching and learning in PE (Marttinen et al., 2020). Furthermore, a study by Baek, Jones, Bulger, and Taliaferro (2018) examined PE teachers' perceptions of and perceived value of technology-related learning across three formal training experiences (pre-service education, in-service CPD, and graduate education), and provided an important insight from the perspective of the PE teacher in that technology experiences must be dynamic, authentic, and tailored for individuals at different stages of technology adoption.

According to Goodyear and Armour (2018), young people are both critical and vulnerable users and generators of digital health technologies. Casey et al., (2017) argue that while we need to be aware of the risks, we also need to explore the opportunities for digital technology to shape PE in new and positive ways. Essentially we must consider the value that a pedagogically driven approach to the use of digital technologies in PE could offer to support young people's learning in a digital age (Casey et al., 2017). The seemingly unstoppable growth in young people's engagement with digital technologies in their personal lives (Rosen, 2010;

Selwyn & Stirling, 2016) means that these technologies are socially and culturally relevant (Casey et al., 2017).

Most recent emerging research by Sargent and Casey (2020), indicates that when used in conjunction with digital technology, flipped learning or a flipped classroom (generally characterised as a pedagogical approach that moves information-transmission teaching out of class and uses class time for learning activities) has the potential to pedagogically support teachers' teaching of PE. This is particularly pertinent given the limited time allocated in the curriculum to PE (some of which is inevitably lost in the changing rooms) and the perceived need for students to be physically active in lessons (Sargent & Casey, 2020). While further research is warranted, flipped learning or a flipped classroom is potentially a fruitful and beneficial pedagogical approach to explore as the digitisation of PE continues (Sargent & Casey, 2020).

The recent coronavirus (COVID-19) pandemic (Xu et al., 2020; Zhu & Chen, 2020) provided further justification and indeed magnification for the integration of digital technology throughout the PE curriculum as a whole, such was the necessity for a virtual learning environment (VLE). Ultimately, we must embrace the significant potential for teachers to connect young people's uses of digital technology with their learning experiences in PE (Casey et al., 2017). Indeed, because digital technology already provides an accessible and potentially rich resource for learning about health, PA and the body, it could also provide a useful resource for teachers to construct and deliver forms of knowledge to young people in ways that are engaging, immediate and attractive (Casey, Goodyear, & Armour, 2016; Casey et al., 2017). Marttinen et al., (2020) argue, however, that future research must continue to explore the intersection between specific digital technologies, ways in which they are used pedagogically, and how they connect to students' lived experiences. Furthermore, as highlighted earlier in this section, close attention must be paid to the ways in which teachers' perceptions and PE ideologies could be augmenting or limiting the educational value of digital technologies in PE. Future research should also continue to explore positive examples of digital technology integration in PE (Marttinen et al., 2020).

2.4.3 Perceived Motor Competence

Perceived motor competence (PMC) refers to an individual's perception of their actual movement capabilities (i.e., an individual's perceived ability to perform a skill) (Babic et al., 2014; Estevan & Barnett, 2018; Harter, 1999; Robinson et al., 2015; Seabra et al., 2013). It is worth noting that within the literature, terms such as physical self-concept, perceived sports competence and perceived physical (self-) confidence are used simultaneously and interchangeably with PMC (Estevan & Barnett, 2018). Researchers are becoming increasingly more aware that PMC plays a critical role in the continued development of movement across the lifespan (Hulteen et al., 2018).

PMC also has a potential effect on PA participation, so much so that actual and PMC have been previously reported to be inextricably linked (Barnett et al., 2011). Indeed, PMC has been conceptualised by Stodden et al., (2008), Robinson et al., (2015) and recently by Hulteen et al., (2018) in theoretical models as a mediator in order to explain how actual and PMC drive PA levels. In fact, PMC has been shown to mediate the association between MC and PA participation in adolescents (Barnett et al., 2011; Barnett, Morgan, van Beurden, & Beard, 2008; Estevan & Barnett, 2018; Harter, 1982; Hulteen et al., 2018).

Correlations between actual and PMC in previous childhood studies appear inconsistent (Fliers et al., 2010; Khodaverdi, Bahram, Stodden, & Kazemnejad, 2016; Raudsepp & Liblik, 2002), suggesting a misalignment between children's actual and PMC (Bardid, De Meester, et al., 2016). Further research has determined that among the adolescent population globally, actual and PMC are only moderately correlated (De Meester et al., 2016; McGrane, Powell, et al., 2018). It is noted in the literature, however, that as children age their perception of their own MC will align better with their actual performance (Estevan & Barnett, 2018; Stodden et al., 2008). Recent research indicates that adolescents do not underestimate their actual MC levels but conversely, overestimation is common, as adolescents tend to have high levels of perceived fundamental and functional MC (De Meester et al., 2016; McGrane, Belton, Powell, Woods, & Issartel, 2016; McGrane, Powell, et al., 2018; O'Brien et al., 2018; Utesch et al., 2018).

Overestimation of MC has previously been described as a favourable phenomenon by De Meester et al. (2016), as it might be positively associated with autonomous motivation for PE, and higher levels of engagement in PA and sports, especially among adolescents with low actual MC. De Meester et al. (2016), for example, found that Flemish adolescents with relatively high levels of PMC and with low actual MC were more physically active, when compared to adolescents with accurately PMC and low actual MC levels. Therefore, it may be reasonable to suggest that PMC may be an even stronger variable than actual MC for adolescents in terms of autonomous motivation for sport, PE and PA (Bardid, De Meester, et al., 2016).

Conversely, research has also found that children who perceive their MC more accurately (compared to less) show more future engagement within PA (De Meester et al., 2016; Utesch et al., 2018). Indeed, Utesch et al., (2019) also describe realistic estimations as favourable for future PA engagement. Developing the capability, therefore, to accurately estimate MC is suggested to provide more realistic expectations about an individual's competence, and should help to trigger an individual's motivation to improve skills in order to be more successful (De Meester et al., 2016; Harter, 1982).

Research suggests that adolescents need to be educated, through the medium of PE, for example, to improve the ability to correctly assess their own and others' MC (De Meester et al., 2016). As such, PE and youth sports programmes should target both actual and PMC through autonomy supportive teaching, and differentiated instruction, specifically in order to help children become competent and motivated movers (Bardid, De Meester, et al., 2016). PMC needs to be addressed in movement programmes and interventions to increase motivation for sports and global self-worth in a bid to promote (continued) engagement in PA and sports (Bardid, De Meester, et al., 2016). Attempts at mastery engagement are essential for building adolescents perception of their competence (Chan et al., 2016). If students have successful attempts within MC tasks, they are more likely to enjoy the tasks, feel competent, and become highly motivated participants (Harter, 1978). Finally, researchers must be cognisant that an individual's physical and psychological development is a complex and multifaceted process, that synergistically evolves across time (Robinson et al., 2015).

Estevan and Barnett (2018) recommend testing the relationship between actual MC, PMC and cognitive development in order to analyse how these three factors interact. According to Bardid et al., (2016), future research should include a longitudinal approach to investigate the dynamic relationship between MC and PA, and the mediating role of PMC. Furthermore, it is suggested that instruments characterised by an alignment between actual and PMC assessments will help us understand more about the motor perceptions of children and adolescents (Estevan & Barnett, 2018).

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Chapter 3

Do Irish adolescents have adequate functional movement skill and confidence?

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3.0 Independent contribution to this chapter

- ✓ I wrote the first draft of this paper and contributed significantly to the subsequent redrafts until publication.

- ✓ Alongside the leading author, Dr. Wesley O'Brien, I was the principal investigator responsible for all data collected (April/May 2016) in this chapter.

- ✓ I planned and organised the data collection. This included contacting the two post-primary schools (i.e., principals, teachers, and subsequently parents and students) involved in this phase of the study, timetabling undergraduate students from the B. Ed. Sports Studies and Physical Education programme, sourcing and preparing necessary equipment, data storage, data cleaning and data inputting.

- ✓ A significant component of this cross-sectional study was the rigorous and robust field researcher training workshop in the measurement protocol associated with FMS, FMS™, and body composition. Dr. Wesley O'Brien organised the procurement of field assistants and I then delivered the training workshop, under his supervision.

- ✓ Dr. Wesley O'Brien and I, as principal investigators, conducted interrater reliability together and I then scored and analysed the data before compiling the results presented in this chapter.

3.1 Abstract

Recent research has shown that post-primary Irish youth are insufficiently active and fail to reach a level of proficiency across basic fundamental movement skills. The purpose of the current research was to gather cross-sectional data on adolescent youth, differentiated by gender, specifically to inform the development of a targeted movement-oriented intervention. Data were collected on adolescents (N = 219; mean age: 14.45 ± 0.96 years), within two, mixed gender schools. Data collection included actual and perceived movement measurements; comprising of fundamental movement skills, the functional movement screen, perceived movement confidence and perceived functional confidence. Overall, levels of actual mastery within fundamental and functional movement were low, with significant gender differences observed. Adolescent males scored higher in the overall fundamental movement skill domain (male mean score = 70.87 ± 7.05; female mean score = 65.53 ± 7.13), yet lower within the functional movement screen (male mean score = 13.58 ± 2.59), in comparison to their female counterparts (female mean score = 14.70 ± 2.16). There were high levels of perceived confidence reported within fundamental and functional movement scales. Future intervention strategies should combat the low levels of actual movement skill proficiency, whilst identifying the reasons for higher perceived movement confidence within adolescents.

Keywords: fundamental movement skill, functional movement screen, motor development

3.2 Introduction

Physical literacy has been previously defined as having the motivation, confidence, physical competence, understanding, knowledge, skills and attitudes to live a physically active life (Whitehead, 2007). Movement competency, an integral component of physical literacy, has been shown to be an important correlate of regular physical activity (PA) participation and health-related fitness in children and adolescents (Cattuzzo et al., 2016; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Indeed, it could be argued that movement competency is a fundamental aspect of childhood development, such is its impact on current and future health (Stodden et al., 2008).

A previous systematic review, which identified 21 potentially relevant articles, was undertaken to examine the association between fundamental movement skill (FMS) competency and eight potential benefits in youth, namely global self-concept, perceived physical competence, cardio-respiratory fitness, muscular fitness, weight status, flexibility, PA and reduced sedentary behaviour (Lubans et al., 2010). From this review, conclusive positive associations between FMS competency and PA, and FMS competency and cardio-respiratory fitness were found, with an inverse association between FMS competency and weight status also identified. Likewise, a previously published longitudinal study highlights that the consequences of ineffective movement skills during childhood can have a significant impact on PA participation later in adolescence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009). While it has been established that levels of PA participation decline significantly during adolescence (Hallal et al., 2012; Woods, Tannehill, Quinlan, Moyna, & Walsh, 2010), evidence suggests that competency in a range of FMS may serve as a protective factor against this trend (Barnett et al., 2009; Lubans et al., 2010). Strategies to improve PA participation may need to consider ensuring that adolescents have competency in basic movement patterns (Belton, O'Brien, Meegan, Woods, & Issartel, 2014; Hardy, Barnett, Espinel, & Okely, 2013; O'Brien, Belton, & Issartel, 2016a, 2016b), at both a fundamental and functional movement level (Abraham, Sannasi, & Nair, 2015; Cook, Burton, & Hoogenboom, 2006a, 2006b). Although there is acceptance that movement competency is multidimensional in nature (Rudd et al., 2016; Whitehead, 2010), there is still a lack of agreement about how movement competency during childhood is comprised. One important reason for this lack of consensus may be the variances in methodological measurements used for movement competency (Giblin, Collins, & Button, 2014), specifically the wide array of movement skill assessment tools (Cools, De Martelaer, Samaey, & Andries, 2009).

FMS are the basic observable building blocks or precursor patterns of the more specialised, complex skills, used in organised and non-organised games, sports and recreational activities (Hands, 2012). Examples exhibited during sport, exercise and PA include running, hopping, skipping (locomotor), throwing, catching, kicking (object control), balancing, twisting and dodging (stability) (Department of Education Victoria, 1996; Gallahue, Ozmun, & Goodway, 2012). Previous evidence suggests that children have the developmental potential to master most FMS skills by six years of age (Gallahue et al., 2012).

In addition to the basic observable patterns of FMS, another indicator for actual movement skill proficiency in adolescents exists. Functional movement relates to the body's use of multi-planar and multi-joint movements, specifically those activating the core musculature region (Abraham et al., 2015). The Functional Movement Screen (FMS™) (Cook, Burton, Fields, & Kiesel, 1998; Cook et al., 2006a, 2006b) is a pre-participation evaluation tool that comprises a series of movements designed to assess multiple domains of function and the quality of movement patterns (Letafatkar, Hadadnezhad, Shojaedin, & Mohamadi, 2014; O'Connor, Deuster, Davis, Pappas, & Knapik, 2011). Previous research has reported low levels of functional movement among children and adolescents (Abraham et al., 2015), further differentiated by observational gender and weight status associations during childhood (Duncan & Stanley, 2012; Schneiders, Davidsson, Hörman, & Sullivan, 2011). If such suboptimal movement strategies persist, there is a suggestion that this may lead to orthopaedic abnormality (e.g.,'s arthritis, low back pain, osteoporosis) in later life (Duncan, Stanley, & Leddington Wright, 2013). Thus, understanding fundamental and functional movement during adolescence may provide a more insightful understanding within the motor development domain.

International based research, particularly with high school students in the USA (Sorenson, 2009; Wieczorkowski, 2010), suggests that a proactive, functional training approach can enhance overall wellness and productivity in active populations. Although, the FMS™ has been used in injury-related research, it was originally designed to assess functional mobility and postural stability (Cook et al., 2006a, 2006b). It is therefore logical to suggest that children who show high levels of functional movement, may also show higher levels of FMS proficiency, as functional mobility and postural stability underpin performances in the basic observable patterns of running, hopping, jumping, and throwing (Kraus, Schutz, Taylor, & Doyscher, 2014). This suggestion is based on the assumption that strength, movement, flexibility and stability are prerequisites for fundamental skill performance, which the FMS™ purports to examine (Kraus et al., 2014). However, no study to date appears to have examined this.

Within the discipline of motor development, many studies refer to perceived competence (perceived ability to perform a skill) (Babic et al., 2014; Seabra et al., 2013), while far fewer refer to perceived confidence (perception of ability/self-efficacy), specifically within the adolescent population (McGrane, Belton, Powell, Woods, & Issartel, 2016). Perceived self-confidence is a key tenant of physical literacy, and is therefore, important to examine.

Perceived self-efficacy is defined as the belief in ones capabilities to organise and execute the courses of action required to manage prospective situations (Bandura, 1994). Previous research has highlighted the importance of assessing adolescents' skill-specific, physical self-confidence levels, across males and females (McGrane, Belton, Powell, & Issartel, 2017; McGrane et al., 2016). The assessment of adolescents' physical self-confidence, at a skill-specific level, has been reported to provide information on the confidence and FMS proficiency levels of participants, which may assist in the creation of an optimal motivational climate for movement (McGrane et al., 2016). Dweck (1991) has outlined that those who possess a high performance ability, and a high self-confidence, will continue to choose challenging tasks provided they have a chance of achieving success.

The development of a valid and reliable instrument to assess physical self-confidence in adolescents, and at a skill specific level has only been recently established (McGrane et al., 2016). This scale can be used to identify adolescents with low self-confidence, as being at risk of ceasing participation in PA and sport, as well as not achieving high levels of FMS proficiency (McGrane et al., 2016). Yet, while the relationship between actual movement skill proficiency and PA participation is empirically established (Lubans et al., 2010), fewer studies have focused specifically on the perceived confidence levels amongst adolescents.

Some empirical research on actual and perceived FMS confidence levels has been conducted previously with adolescents (McGrane et al., 2017), however, no study published to date has examined the actual and perceived functional confidence levels amongst adolescents. In order to better target interventions aimed at enhancing movement skill proficiency and subsequent PA in adolescence, there is a need to better understand how perceived confidence may be related to both fundamental and functional movement during early adolescence. The purpose of the current research was to gather cross-sectional data on Irish adolescent youth, differentiated by gender, specifically in order to inform the development of a targeted movement-based intervention.

3.3 Methods

3.3.1 Overview of the Study

Cross-sectional data to inform the design of a larger multi-component, movement based physical education (PE) intervention for post-primary schools in Ireland was collected, as part of a research programme which was initiated in

October 2015. Cross-sectional data, differentiated by gender-based comparisons, for the present study were gathered over a six-week period in April and May 2016, which specifically included FMS, FMS™, PA (accelerometry and self-report), perceived movement skill confidence and anthropometric characteristics (height and mass).

Ethical approval for this study was provided by the Social Research Ethics Committee (SREC) in University College Cork (March 2016). Prior to the commencement of this school-based study, the leading researcher visited the principal of each of the participating schools, where a full brief and outline of the data collection was provided. Subsequent to the granted approval from school principals, information sheets and consent forms were then distributed to the selected class groups. Informed parental consent and child assent were the requirements for eligible participation in this study. All participants were free to withdraw from the research at any stage.

3.3.2 Participants and Setting

A convenience sample (based on the researchers' proximity to the schools) of cross-sectional data was collected on Irish adolescent youth, as part of the study protocol. In terms of the research rigour associated with school-based measurements, it is important to note that the leading investigators for this study are qualified post-primary specialist PE teachers, as recognised by the Teaching Council of Ireland.

Consenting post-primary participants enrolled in years one to three (12–16 years) from two, mixed gender, non-fee paying schools, were invited to partake.

Both post-primary schools involved in the research study were from the same urban area in County Cork, within the province of Munster, Ireland. Two hundred and twenty-seven participants from the two schools were invited to participate in this study, with consent from 219 participants provided (97% of total sample). Of the participants, 120 were male (55%) and 99 were female (45%); 89 adolescents were in year one (40%), 52 adolescents were in year two (24%) and 78 adolescents were in year three (36%). The mean age of the participants was 14.45 ± 0.96 years (age range: 12.82 – 16.37 years old). The current sample of boys and girls provides the opportunity to compare and contrast mastery levels of adolescents.

3.3.3 Data Collection

Prior to data collection, all thirteen field staff, who were final year undergraduate pre-service PE teachers, underwent a rigorous and robust 8 hour field researcher training workshop in the measurement protocol associated with FMS, FMS™, self-report questionnaires, accelerometry and body composition. This involved an objective, criteria-informed process to ensure field staff were consistent in the administration and implementation of the respective gross motor skill and movement task(s). Cross-sectional data to inform the development of the intervention was collected on participants in their class groups (maximum n = 30) during specific school visits. Objective measurements, such as FMS and FMS™ were carried out during a typical PE class, while subjective self-report questionnaire measurements were taken during a separate school visit in a computer lab, using the online tool of 'Survey Monkey' for participant responses.

3.3.4 Measures

3.3.4.1 Fundamental Movement Skills

The following 10 FMS were assessed: run, skip, horizontal jump and vertical jump (locomotor, maximum score of 34); two-handed strike, stationary dribble, catch, kick, overhand throw (object control, maximum score of 40) and balance (stability, maximum score of 10), which combines to give an overall maximum raw score of 84. Process-oriented assessments of FMS were used in preference to product-oriented assessments because they identify more accurately specific topographical aspects of the movement (Logan, Barnett, Goodway, & Stodden, 2017; Ulrich, 2000). Each of the ten FMS were assessed in conjunction with the observable, behavioural components from three testing batteries with established reliability and construct validity (Cools et al., 2009; Department of Education Victoria, 1996; Ulrich, 1985), namely the Test of Gross Motor Development (TGMD) (Ulrich, 1985) (skip), TGMD-2 (Ulrich, 2000) (run, horizontal jump, two-handed strike, stationary dribble, catch, kick and overhand throw) and the Victoria Fundamental Motor Skills manual (Department of Education Victoria, 1996) (balance and vertical jump). These instruments were selected to give an objective measurement of gross motor skill proficiency across a range of skills, including those skills particularly relevant to the Irish sporting context and PE environment (O'Brien et al., 2016a).

Prior to participant performance, one trained field staff member provided an accurate demonstration and instruction of the skill to be performed. Procedures outlined in the TGMD-2 examiner's manual (Ulrich, 2000) were closely adhered to within the assessment of the ten FMS during the selected PE period. This process for

FMS measurement has been reported previously in an Irish adolescent context (O’Brien et al., 2016a, 2016b). To ensure participant consistency within skill performance, no feedback, verbal or otherwise, from any of the trained field staff was given during the testing. Participants performed the skill on three occasions, including one familiarisation practice, and two performance trials, as reported in previous Irish adolescent movement skill data collection protocol (McGrane et al., 2017; O’Brien et al., 2016a, 2016b). The number of performance criterion varied from three to six across the range of selected FMS; all participants were given a ‘1’ for correct execution of a criterion and a ‘0’ for a failure on a criterion. For each FMS, the two performance trials were added together to get the total for each skill score which equated to the total of 84 across the ten skills (O’Brien et al., 2016a). Video cameras (3 × Canon type Legria FS21 cameras; Canon Inc., Tokyo, Japan and 2 x Apple iPads) were used to record each participant’s performance and execution of the required skill. The distance and camera angles were at all times consistent; specifically, to ensure that the complete body movement was captured (O’Brien et al., 2016a, 2016b). The use of video-recording is an important consideration in data collection as it permits greater scrutiny and therefore accuracy of measurement precision (Okely & Booth, 2004). The FMS scoring process including the assessment of the behavioural components of each skill was completed at a later date by the principal investigators.

3.3.4.2 Functional Movement Screen

The following seven functional movements were assessed: active straight-leg raise, deep squat, hurdle step, in-line lunge, rotary stability, shoulder mobility and trunk stability push-up (Cook et al., 1998). The test administration procedures, instructions and scoring process associated with the standardized version of the test (Cook et al., 2006a, 2006b) were followed in order to ensure accuracy in scoring (Abraham et al., 2015; Bardenett et al., 2015). Normative values have been established for the FMS™ in adolescent school-aged children (Abraham et al., 2015). Trained field staff utilised the pre-determined verbal instructions during testing. During data collection, each participant was again video-recorded, and given three attempts to perform the movement. It should be noted that all trained field staff scored the optimum trial stringently at a later date, as recommended in the original training workshop.

The FMS™ has a scoring range from zero to three, with three being the optimum score (Cook, 2010). If at any time during the testing, the participant demonstrated or acknowledged pain or discomfort, anywhere in the body, he/she received a score of zero and the area noted. A score of one was given to a participant, if they were unable to complete the movement. If the participant had to use a compensation, for example, lifting one's heels off the ground during the deep squat, to perform the movement, a score of two was allocated. A maximum score of three was allocated if the participant performed the movement correctly without any compensation. Bilateral scores for five (active straight-leg raise; hurdle step; in-line lunge; rotary stability and shoulder mobility) of the seven functional movements were also recorded, as a means to compare possible imbalances between the right and left sides of the body for participants. The lowest score for either side of the body within each movement contributed to the final scoring protocol. For each of the seven screening items, the highest score from the three trials was recorded and used to generate an overall composite FMS™ score, with a maximum value of 21, as part of established and recommended protocol (Cook et al., 2006a, 2006b; Duncan & Stanley, 2012; Schneiders et al., 2011). On account of the video-recording set-up for data collection, the FMS™ scoring process was completed at a later date by the principal investigators, with each component test scored on an ordinal scale, and total composite score then calculated.

3.3.4.3 Perceived Movement Confidence

The physical self-confidence scale (McGrane et al., 2016) was used as an indicator to measure the perceived movement confidence of participants' in their FMS proficiency. As previously reported, this adolescent measurement tool has excellent test-retest reliability (r = 0.92) (McGrane et al., 2016). Furthermore, the scale demonstrates good content and concurrent validity (r = 0.72), when compared to the physical self-perception profile (Harter, 1985). Within this physical self-confidence scale, participants were asked to rate their confidence at performing 15 FMS, based on a Likert scale format of 1-10. A score of '1' indicated being not confident at all and a score of '10' indicated being very confident. This is the first valid and reliable instrument that has been developed to assess physical self-confidence in adolescents, and at a skill specific, FMS proficiency level. Furthermore, it is worth noting that the identified skills included within this instrument are deemed central to the Irish adolescent sporting culture (O'Brien et al., 2016a; Woods et al., 2010). In the current study, the physical self-confidence scale for perceived movement confidence has excellent internal consistency, with a Cronbach alpha coefficient of 0.94.

3.3.4.4 Perceived Functional Confidence

As part of this study, the researchers have also developed a tool to assess perceived functional movement confidence amongst an Irish adolescent population. The developed functional movement confidence scale was further used as an indicator to measure the perceived movement confidence of participants' in their FMS™ proficiency at baseline. Similar to the McGrane et al., (2016) protocol, participants were asked to rate their confidence at performing the identified 7 FMS™ tasks, based on a Likert scale format of 1-10, as part of this functional movement confidence scale. A score of '1' indicated being not confident at all and a score of '10' indicated being very confident. This is the first instrument that has been developed to assess perceived functional movement confidence in adolescents. As the FMS™ tasks are non-sport specific, it was decided that a visual image alongside the question would be provided (Barnett, Ridgers, & Salmon, 2015; Barnett, Vazou, et al., 2016), in support of a previously validated pictorial instrument for assessing FMS perceived competence. To ensure that adolescent performance was consistent over time across the 7 selected perceived functional confidence items, trained field staff conducted a 48-hour time sampling test–retest reliability measurement amongst a sample of 23 participants, aged 12 to 14 years old. The coefficients for the 7 items ranged from 0.82 to 0.93, showing the scores across the 7 perceived functional confidence items to be stable over time. Furthermore, in the current study, the perceived functional movement confidence scale has excellent internal consistency, with a Cronbach alpha coefficient of 0.92.

3.3.5 Data Analysis

Once data collection was complete, the principal investigators were required to reach a minimum of 95% inter-observer agreement for all ten FMS and seven FMS™. The actual and perceived FMS and FMS™ data sets were analysed using SPSS version 20.0 for Windows. Descriptive statistics and frequencies for FMS and FMS™ at the skill and composite score levels were calculated, according to their associated gender breakdown. For the FMS and FMS™ constructs in this study, 'Mastery' was defined as correct performance of all skill components on both trials (Booth, Denney-Wilson, Okely, & Hardy, 2005; O'Brien et al., 2016a). Gender differences in overall and individual FMS/FMS™ performances were analysed using independent sample t-tests and Mann-Whitney U tests. Statistical significance was set at $p < .05$.

3.4 Results

3.4.1 Fundamental Movement Skills

Of the 181 students with full FMS data, no student possessed complete mastery level across all ten skills. The mean overall composite score was 68.72 ($\pm$ 7.54), out of a possible total of 84. The highest skill performance was the catch, with 86.6% achieving complete mastery. The poorest performance was for the horizontal jump, where only 14.8% achieved complete mastery.

The mean skill score and standard deviation (SD) for all ten FMS amongst males and females are shown in Table 3.1, while the percentage of complete mastery, differentiated by gender is shown in Figure 3.1.

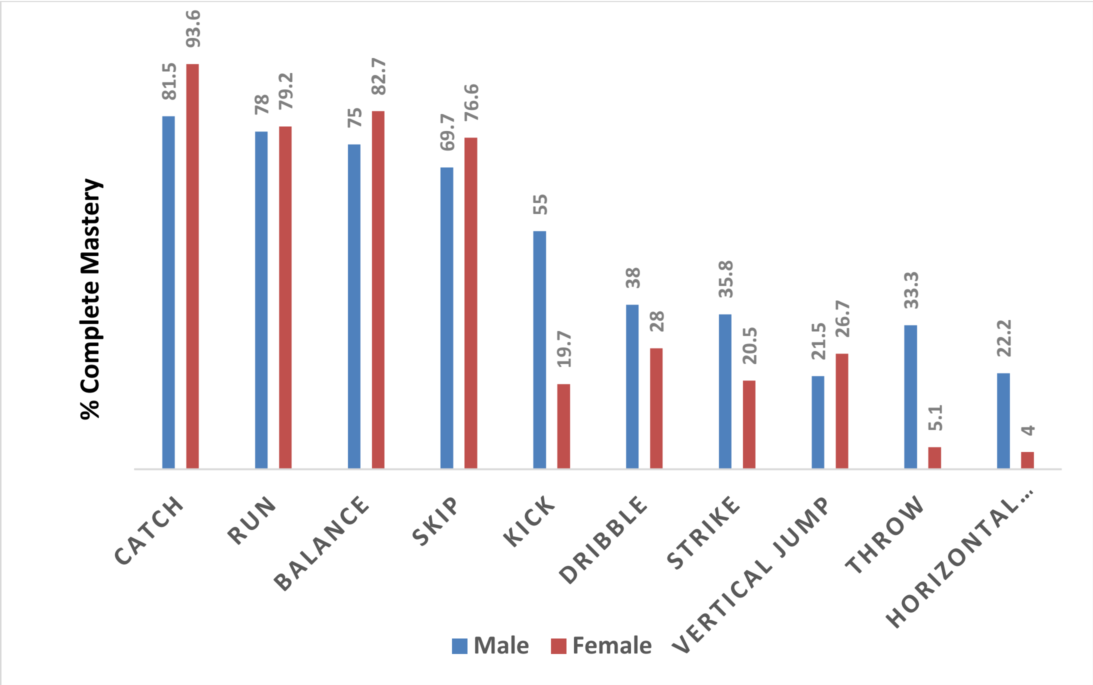

Figure 3.1: Percentage Mastery of Fundamental Movement Skills (FMS) by gender.

Table 3.1: Mean scores for Fundamental Movement Skill (FMS) proficiency and Physical Self-Confidence by gender.

	FMS			PSC	
Skill	Male	Female	Maximum possible score	Male	Female
Balance	9.44 SD = ±1.18	9.59 SD = ±1.05	10	8.77 SD = ±1.85	8.48 SD = ±1.80
Catch	5.44 SD = ±1.38	5.88* SD = ±0.53	6	9.22* SD = ±1.77	8.55 SD = ±1.98
Dribble	6.48 SD = ±1.60	6.11 SD = ±1.57	8	9.29* SD = ±1.55	8.84 SD = ±1.75
Horizontal Jump	6.02** SD = ±1.61	5.01 SD = ±1.70	8	8.17** SD = ±2.19	6.77 SD = ±2.54
Kick	7.02** SD = ±1.31	5.18 SD = ±1.99	8	9.34** SD = ±1.79	8.19 SD = ±2.29
Run	7.59 SD = ±0.87	7.51 SD = ±1.05	8	9.09* SD = ±1.76	8.56 SD = ±2.01
Skip	5.33 SD = ±1.26	5.55 SD = ±0.99	6	8.58 SD = ±2.26	8.40 SD = ±2.05
Strike	8.51** SD = ±1.34	7.40 SD = ±2.18	10	8.54** SD = ±2.12	6.75 SD = ±2.56
Throw	5.56** SD = ±2.21	3.73 SD = ±1.91	8	9.31** SD = ±1.41	8.48 SD = ±1.77
Vertical Jump	9.45 SD = ±1.95	9.53 SD = ±1.92	12	8.60** SD = ±1.97	7.35 SD = ±2.44

[$*p \leq 0.05$; $**p \leq 0.001$]

When broken down by gender, a Mann-Whitney *U* test revealed a significant difference in the overall gross motor score, with males scoring higher than females (p = .001). At the subset level, males performed significantly higher in the overall object control domain (p = .001), when compared to females; specifically, males performed higher in three of the five object control skills assessed (kick (p = .001), strike (p = .001), throw (p = .001)) although females did perform significantly better in the catch (p = 0.003). There was no significant gender difference found in overall locomotor skill performance. Males did, however, perform significantly higher in the horizontal jump (p = .001), when compared to females.

3.4.2 Functional Movement Screen

Twenty nine of the original 181 participants were subsequently omitted from the functional movement screening data set, specifically as a result of incomplete camera angle footage, and missing data. Of the 152 students with full Functional Movement Screen data, no student achieved complete mastery across all seven tests (maximum score of 3 for all). The mean composite score was 14.05 $\pm$ 2.48 out of a possible total of 21. An independent samples *t*-test revealed a significant difference in the overall composite functional movement screen raw score between gender, with females (p = .011) performing better than males. When broken down by specific screening items, females displayed significantly higher functional movement proficiency in the active straight leg raise (p = .001), and the shoulder mobility (p = .005) test, while males displayed significantly higher functional movement proficiency in the trunk stability push-up test (p = .001). The mean FMS™ score and standard deviation (SD) for all seven screening measurements amongst males and females are shown in Table 3.2, while the percentage of complete mastery, differentiated by gender is shown in Figure 3.2.

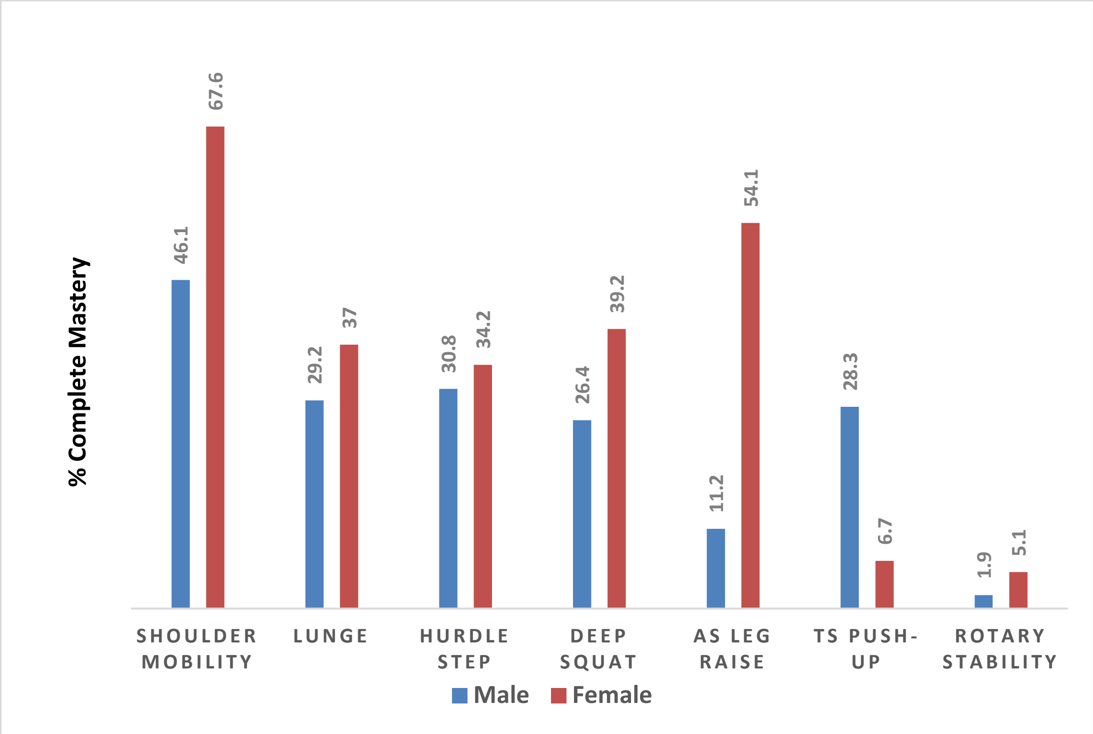

Figure 3.2: Percentage Mastery of the Functional Movement Screening (FMS™) items by gender.

[*AS* = Active Straight; *TS* = Trunk Stability]

Table 3.2: Mean scores for the Functional Movement Screening (FMS™) items and Physical Self-Confidence by gender.

	FMS™			PSC	
FMS™	Male	Female	Maximum possible score	Male	Female
AS Leg Raise	1.69 SD = ±0.67	2.38** SD = ±0.75	3	7.74 SD = ±2.26	7.47 SD = ±2.32
Deep Squat	1.78 SD = ±0.84	2.01 SD = ±0.88	3	7.63 SD = ±2.37	7.41 SD = ±2.26
Hurdle Step	2.30 SD = ±0.48	2.34 SD = ±0.48	3	8.24** SD = ±1.95	7.11 SD = ±2.22
In-Line Lunge	2.26 SD = ±0.51	2.36 SD = ±0.51	3	7.94 SD = ±2.16	7.38 SD = ±2.29
Rotary Stability	1.75 SD = ±0.52	1.78 SD = ±0.53	3	8.12** SD = ±2.24	6.97 SD = ±2.18
Shoulder Mobility	2.16 SD = ±0.89	2.51* SD = ±0.76	3	8.28* SD = ±2.01	7.62 SD = ±2.05
TS Push-Up	1.68** SD = ±0.89	1.15 SD = ±0.51	3	7.77** SD = ±2.40	6.60 SD = ±2.37

[*AS* = Active Straight; *TS* = Trunk Stability; *$p \leq 0.05$; **$p \leq 0.001$]

3.4.3 Perceived Movement Confidence

There were significant gender differences observed in physical self-confidence, with males scoring significantly higher than females in eight of the ten individual skills, as highlighted in Table 3.1. This included all five object control skills (dribble (p = 0.05), kick (p = 0.001), strike (p = 0.001), throw (p = 0.001) and catch (p = 0.013)), as well as three of the locomotor skills (horizontal jump (p = 0.001), vertical jump (p = 0.001) and run (p = 0.046)).

3.4.4 Perceived Functional Confidence

Again, when broken down by gender, a Mann-Whitney *U* test revealed considerable gender differences, with males scoring significantly higher than females (p = .001) in their overall perceptions of perceived functional confidence. As indicated within table 3.2, there were also significant gender differences observed amongst four of the seven individually perceived functional movement screening items, including the hurdle step (p = .001), rotary stability (p = .001), shoulder mobility (p = .021) and trunk stability push-up (p = .001), with males having higher perceived functional confidence at the individual item level.

3.5 Discussion

The availability of successful evidence-based programmes targeting motor development, particularly in the early childhood and pre-pubescent literature, has paved the way for the implementation of other FMS movement-oriented interventions to address the identified needs within specific populations (Barnett et al., 2013; Mitchell et al., 2013; O'Brien, Issartel, & Belton, 2013; van Beurden et al., 2003). To the authors' knowledge, this cross-sectional collected data is the first study to combine both fundamental and functional movement assessment in adolescence. It is intended that these cross-sectional findings will help inform the design and development of the larger, movement-oriented intervention, at a later stage.

The current cross-sectional study heightens the reader's understanding of the trends in actual and perceived movement confidence, differentiated by gender within the Junior Cycle years of Irish post-primary education. Generally, results of the present cross-sectional study highlight that a large proportion of Irish adolescent youth are lacking both fundamental and functional movement skill proficiency. Specifically, no participant demonstrated overall mastery across the range of selected FMS and/or the FMS™, irrespective of the associated gender breakdown. In the present study, participants appear to have considerably higher perceived movement, and higher perceived functional confidence levels, when compared to their actual skill proficiency in FMS and FMS™. On the perceived movement and functional confidence scales (0–10), participant mean values were generally in the upper thresholds (mean values of ≥7 within tables 3.1 and 3.2), indicating higher levels of perceived confidence amongst this selected mixed-gender cohort. This is aligned with recent research on an Irish cohort, which highlighted that adolescent males in particular consistently scored a mean of 8 or above (out of 10) in confidence, regardless of their actual ability (McGrane et al., 2017).

In terms of actual FMS proficiency, overall skill execution is low amongst the selected adolescent youth, supporting most recent motor development literature within Ireland (Belton et al., 2014; O'Brien et al., 2016a). When broken down by gender, and consistent with research informed FMS literature, males appear to have higher movement skill proficiency within the object control subset, when compared to females (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; O'Brien et al., 2016a; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). It is possible that the gender differences in object control skills could be predominantly environmental rather than biological, and there is a good chance that these gender differences could be reduced if girls are provided with the same opportunities for instruction, practice, feedback and encouragement as boys (Okely & Booth, 2004; Thomas & French, 1985). Development of proficiency in object control skills has been identified as a stepping stone to help learn PE content with greater success and enjoyment in adolescence while those with object control skill proficiency are more likely to play organised and non-organised sports, and also are at an increased likelihood of participating in specific physical activities during the adolescent years (Barnett, Lai, et al., 2016; Barnett et al., 2009; Chen, Hammond-Bennett, & Hypnar, 2017; Hardy, King, Farrell, Macniven, & Howlett, 2010; Lander, Eather, Morgan, Salmon, & Barnett, 2017; Okely, Booth, & Patterson, 2001). Interestingly, there were no gender differences within overall locomotor performance. These overall low FMS findings are in line with most recent research carried out on adolescents in a different region of Ireland (O'Brien et al., 2016a), and support the statement that Irish youth may be engaging in sport-specific skills, without learning the prerequisite criteria for basic skills and movement patterns. Considering the future directions of this research, it is reasonable to suggest based on the current findings that strategies for FMS proficiency need to be integrated within the intervention, with specific directional emphasis towards object control skill development for females, and overall locomotor jumping (vertical and horizontal) opportunities for participants. Indeed, actual movement skills are one of the few modifiable risk factors for the prevention of poor health outcomes (Bremer & Cairney, 2016), and therefore promoting movement skill proficiency is integral to a holistic view of development (Barnett, Stodden, et al., 2016).

Similar to the low levels of FMS proficiency observed in the present study, overall functional movement skill execution is also low amongst participants, which is consistent with other previously published functional movement adolescent literature (Paszkewicz, McCarty, & van Lunen, 2013; Portas, Parkin, Roberts, & Batterham, 2016). Overall, the mean composite FMS™ raw score for this study was 14.05 (out of a possible 21), which is similar to the mean values reported by Abraham et al., (2015) on 1005 mixed-gender adolescents in India. Interestingly, when broken down by gender, Abraham et al., (2015) found statistically significant differences, with males outperforming their female counterparts. Although conflicting evidence regarding the effect of gender on total mean FMS™ scores exist, lower total FMS™ scores have been reported for female secondary school youth (Anderson, Neumann, & Huxel Bliven, 2015) and female adolescent (Abraham et al., 2015) athletes, when compared to males of the same age (Martin et al., 2017). Despite the convenience sample, and lower number of participants (n = 152), data from this research appear to go against previous findings as females outperformed males in their overall functional movement. In support of the current study, Schneiders et al. (2011) found similar significant differences between female [higher efficiency on the active straight leg raise and the shoulder mobility tests] and male [higher efficiency on the trunk stability push-up test] participants on individual FMS™ tests, suggesting that there may be adolescent gender-based differences within both FMS and FMS™ assessment protocol. In terms of future intervention design and development, findings suggest that overall functional movement development may need to be addressed, with specific developmental opportunities provided for male Irish adolescent youth. Previous research informed data on functional movement, as measured by the FMS™, suggests that structured interventions lead to positive movement-based outcomes (Kiesel, Plisky, & Butler, 2009).

Interestingly, results of this cross-sectional study indicate that the perception of males in relation to their movement confidence, does not equate to their actual movement skill proficiencies. Although males have higher perceptions of their skill-specific ability than females, particularly within their perceived functional confidence levels, they have lower actual skill proficiency when compared to their female counterparts, specifically in six of the seven movement screening tasks. These findings are significant on a number of levels, as they accentuate the need to analyse the relationship between actual and perceived movement, as separately by gender, in the adolescent population. The varying gender discrepancies in the perceived movement and functional confidence levels highlight that some adolescents may require different attention and a tailored intervention focus, specifically targeting their requirements, as previously acknowledged by McGrane et al., (2017). Indeed, assessing actual FMS and FMS™, and perceived movement and functional confidence levels highlights those in most need of an intervention, but also facilitates the potential development of an adolescent movement-based intervention in Ireland.

In light of this study, it may be plausible that despite the low levels of actual skill competence at both fundamental and functional movement levels, Irish adolescents may be inaccurately overestimating their perceived confidence levels for movement. Previous research within social psychology research has documented the existence of positive illusory bias within the general population (De Meester et al., 2016; Owens, Goldfine, Evangelista, Hoza, & Kaiser, 2007), and further research indicates that there is a positive bias among children and adolescents with learning disabilities in their predictions of performance (Heath & Glen, 2005). While results from the present study heighten the need for improving low actual movement skill competencies amongst Irish adolescents, the observed high perceptions for movement across both genders could be argued as a benefit. For example, De Meester et al., (2016) highlighted that a specific cohort of adolescents who overestimated their perceived motor competence were more autonomously motivated for PE and sufficiently active, when compared to their peers with accurate perceptions of motor competence. While overestimating perceptions of movement may be a favourable outcome for physically active pursuits in adolescents with low actual movement skill proficiency (De Meester et al., 2016), this has yet to be confirmed within an Irish adolescent cohort in a longitudinal capacity.

Creating a change in PA behaviour and movement skill proficiencies during adolescence requires a multi-faceted approach (Bremer & Lloyd, 2014; O'Brien, Belton, & Issartel, 2015), with the necessity of creating developmentally and gender-appropriate activities (Barnett et al., 2010; Lai, Costigan, Stodden, Salmon, & Barnett, 2014; Logan, Robinson, Wilson, & Lucas, 2012; Morgan et al., 2013; Robinson et al., 2015) that positively impact movement proficiency. Indeed, as measured in the present cross-sectional study, components that foster the development of both actual and perceived confidence levels may significantly improve the long-term impact of adolescent movement.

3.5.1 Limitations

A potential limitation of this research is the cross-sectional nature of the study. Furthermore, as the convenience sample of adolescents in this study was limited to just two post-primary schools in one Irish city, any potential findings cannot be generalised to other adolescents. Although reliability and face validity have been identified, future research using the perceived functional confidence scale is needed to establish criterion validity, however, this was the first attempt in an Irish context to collect such data amongst adolescent youth.

3.6 Conclusion

Considering the observed low levels of actual fundamental and functional movement amongst the sample, developing a specifically designed movement-oriented intervention would be a strategic step towards improving the current levels of adolescent movement skill proficiency found in this study. In terms of both perceived movement and functional confidence, participants generally display high levels of confidence, however, these results do not appear to be associated with the actual movement-based tasks. Furthermore, a conflicting gender-based disparity may exist within the next phase of the programme; it appears that females need additional hours of instructional practice towards the acquisition of actual FMS proficiency, whilst males may need additional time devoted to their functional movement development, when compared to their female counterparts. Results from the current study suggest that the future intervention may need to specifically address the low levels of actual movement skill proficiency, with developmentally appropriate strategies for understanding perceived confidence at both the fundamental and functional movement level.

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Chapter 4

The age-related association of movement in Irish adolescent youth

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4.1 Abstract

Background: Research has shown that post-primary Irish youth are insufficiently active and fail to reach a level of proficiency across basic movement skills. The purpose of the current research was to gather cross-sectional data on Irish adolescent youth, specifically the prevalence of movement skills and patterns, in order to generate an overall perspective of movement within the first three years (Junior Cycle) of post-primary education. **Methods:** Data were collected on adolescents (N = 181; mean age: 14.42 ± 0.98 years), attending two, mixed-gender schools. Data collection included 10 fundamental movement skills (FMS) and the seven tests within the Functional Movement Screen (FMS™). The data set was analysed using the Statistical Package for Social Sciences (SPSS) version 20.0 for Windows. **Results:** Overall, levels of actual mastery within fundamental and functional movement were low. There were statistically significant age-related differences observed, with a progressive decline as age increased in both the object control (p = 0.002) FMS sub-domain, and the in-line lunge (p = 0.048) test of the FMS™. **Conclusion:** In summary, we found emerging evidence that school year group is significantly associated with mastery of movement skills and patterns. Results from the current study suggest that developing a specifically tailored movement-oriented intervention would be a strategic step towards improving the low levels of adolescent fundamental and functional movement proficiency.

Keywords: age; fundamental movement skills; functional movement screen; adolescent

4.2 Introduction

Research has established that levels of physical activity (PA) participation decline significantly during adolescence (Hallal et al., 2012; Woods, Tannehill, Quinlan, Moyna, & Walsh, 2010). The ability to perform a variety of fundamental movement skills (FMS) may serve as a protective factor against this trend however (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Lubans, Morgan, Cliff, Barnett, & Okely, 2010), with empirical evidence suggesting that proficiency in FMS is positively associated with PA participation (Fisher et al., 2005; Lloyd, Saunders, Bremer, & Tremblay, 2014; Lubans et al., 2010; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). Therefore, strategies to improve PA participation may need to consider ensuring that adolescents have competency in basic movement patterns (Belton, O'Brien, Meegan, Woods, & Issartel, 2014; Hardy, Barnett, Espinel, & Okely, 2013; O'Brien, Belton, & Issartel, 2016a, 2016b), at both a fundamental and functional movement level (Abraham, Sannasi, & Nair, 2015; Cook, Burton, & Hoogenboom, 2006a, 2006b).

FMS are considered the basic observable building blocks, or precursor patterns of the more specialised, complex movement skills required to successfully participate in organised and non-organised games, sports and recreational activities (Clark & Metcalfe, 2002; Hands, 2012). Examples exhibited during sport, exercise and PA include running, hopping, skipping (locomotor), throwing, catching, kicking (object control), balancing, twisting and dodging (stability) (Department of Education Victoria, 1996; Gallahue, Ozmun, & Goodway, 2012). Previous evidence suggests that children have the developmental potential to master most FMS skills by six years of age (Gallahue et al., 2012).

Children and adolescents who have established a base of FMS may possess some of the tools to be physically active (Butterfield, Angell, & Mason, 2012), and with that, can potentially benefit from a lifetime of health-enhancing PA (Gallahue et al., 2012). Crucially, competency in a range of FMS increases the likelihood of children and adolescents participating in different physical activities throughout their lives (Lloyd et al., 2014; Stodden et al., 2008; Venetsanou & Kambas, 2017). Conversely, those who lack FMS are at an increased likelihood to experience the consequences of "public failure", or ridicule from peers (Rose, Larkin, & Berger, 1994), and subsequently may avoid participation in organised sports. In turn this can then serve to decrease their development toward a physically active lifestyle (US Department of Health and Human Services, 1997). From a public health perspective, low motor competence and FMS performances amongst adolescent youth may relate to the escalating prevalence of childhood obesity (Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012) and weight status (Bryant, Duncan, & Birch, 2014). Movement skills are one of the few modifiable risk factors for the prevention of poor health outcomes (Bremer & Cairney, 2016).

Functional movement is another indicator of actual movement proficiency, as it relates to the body's use of multi-planar and multi-joint movements, specifically those activating the core musculature region (Abraham et al., 2015). Previous research has reported low levels of functional movement among children and adolescents (Abraham et al., 2015; O'Brien, Duncan, Farmer, & Lester, 2018). If such suboptimal functional movement strategies persist, there is a suggestion that this may lead to orthopaedic abnormality (e.g., arthritis, low back pain, osteoporosis) in later life (Duncan, Stanley, & Leddington Wright, 2013).

The Functional Movement Screen (FMS™) has predominantly been used in injury-related research for assessing functional mobility and postural stability (Cook et al., 2006a, 2006b). The FMS™ instrument was conceptualised as a tool that assesses movement patterns and functional movement capacity (Cook et al., 2006a, 2006b). It is therefore logical to suggest that children who show high levels of functional movement, may also show higher levels of FMS proficiency, as functional mobility and postural stability underpin performances in the basic observable patterns of running, hopping, jumping, and throwing (Kraus, Schutz, Taylor, & Doyscher, 2014). This suggestion is based on the assumption that strength, movement, flexibility and stability are prerequisites for fundamental skill performance, which the FMS™ purports to examine (Kraus et al., 2014). Although the FMS and FMS™ share some commonality as movement assessments, it is not a given that an individual who has high levels of skill proficiency in FMS will also score highly in the FMS™. Where this is the case, it may be an indication that they are making significant compensations that will, at best, only temporarily allow for high-level skill-related performance (Cook, Burton, & Fields, 2012). Cook et al. (Cook et al., 2006b, 2006a) identifies functional movement as the base of a movement pyramid with FMS, representing more advanced movement patterns, sitting on top of this. Thus, understanding or considering both fundamental and functional movement as two elements in a continuum of movement competence may provide a more insightful understanding within the motor development domain, by reflecting more accurately the skills and movements inherent in a wider range of sports and games in which adolescents participate.

Age, and thereby previous practice and experience of FMS, is an important factor in the development of FMS (Valentini et al., 2016). For example, a study of four object control skills found improvements were characterized by early, rapid gains at ages 9 to 10, beyond which development occurred at a slower rate for catching, throwing, and kicking, although striking development continued at a steady rate to an age of 14 years (Butterfield et al., 2012). Understanding the trends in FMS competence by sex and age provides practitioners with valuable information to implement instructional and intervention strategies, curriculum development, and policy changes (Valentini et al., 2016). FMS and the process of motor development as a whole is age-related but not always age-determined (Gallahue et al., 2012; O'Brien et al., 2016a). Chronological age, for example, is a poor indicator of maturity due to the individuality and extreme variability of the growth process, particularly during later childhood and early adolescence (Gallahue et al., 2012). However, it can also be difficult to determine biological maturity particularly for practitioners in the field. Similarly, most children, once they gain body control, can pass the FMS™ with minimal difficulty (Cook et al., 2012). During adolescence and puberty, asymmetrical growth occurs between the legs and the upper torso. The lower extremity almost always demonstrates stiffness in the hips and ankles, including tightness in the lateral hip musculature and hamstrings which creates an obvious awkwardness to adolescent movement (Cook et al., 2012). While many adolescents do subsequently rebalance themselves after puberty, some do continue to display poor movement patterns through adulthood (Cook et al., 2012). Ultimately, identifying individuals with a suboptimal movement foundation (Bodden, Needham, & Chockalingam, 2015), as well as any weaknesses and asymmetries could play a key role in enabling lifelong habitual PA and movement (Perry & Koehle, 2013).

Gender-based differences are also apparent within the FMS literature, as males appear to have higher movement skill proficiency within the object control subset, when compared to females (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; O'Brien et al., 2016a; Wrotniak et al., 2006). Gender based FMS™ differences have also been identified within adolescent populations, although the research in this area is currently limited. Previous research (Abraham et al., 2015) found that males were on average better within the in-line lunge, active straight leg raise, trunk stability push-up and the rotary stability tests than females. Most recent research in Ireland found that female adolescents outperformed males in their overall functional movement, specifically six of the seven movements within the FMS™, with the exception of the trunk stability push-up (O'Brien et al., 2018).

The purpose of the current research was to gather cross-sectional data on Irish adolescent youth, specifically in order to generate an overall perspective of movement during the initial three years (Junior Cycle) of post-primary education. This study presents findings on the prevalence of mastery (displaying correct performance on all components of a fundamental movement skill and functional movement pattern) (O'Brien et al., 2016a) for males and females, differentiated by school year group (first year through to third year). It was hypothesized that adolescents' movement skills and patterns would be positively associated with school year group.

4.3 Materials and Methods

4.3.1 Participants and Setting

A convenience sample of cross-sectional data was collected on Irish adolescent youth as part of the study protocol. Students were grouped based on year of enrolment in the school. Ethical approval was provided by the Social Research Ethics Committee (SREC) of University College Cork (March 2016). Prior to the commencement of this school-based study, the leading researcher visited the principal of each of the participating schools, where a full brief and outline of the data collection was provided. Subsequent to the granted approval from school principals, information sheets and consent forms were then distributed to the selected class groups. Informed parental consent and child assent were the requirements for eligible participation in this study. Each school and participant was informed that their participation in the study was entirely voluntary, and that they were free to withdraw from the study at any time. In terms of the research rigour associated with school-based measurements, it is important to note that the principal investigators for this study are qualified post-primary specialist physical education (PE) teachers, as recognised by the Teaching Council of Ireland.

Consenting post-primary participants enrolled in years one to three (12–16 years) from two mixed-gender, non-fee-paying schools were invited to partake. Both post-primary schools involved in the research study were from the same suburban area in County Cork, within the province of Munster, Ireland. Two hundred and twenty-seven participants from the two schools were invited to participate in this study, with consent from 219 participants provided (97% of total sample).

4.3.2 Data Collection

Please refer to 3.3.3 Data Collection in Chapter 3.

4.3.3 Measures

4.3.3.1 Fundamental Movement Skills

Please refer to 3.3.4.1 Fundamental Movement Skills in Chapter 3.

4.3.3.2 Functional Movement Screen

Please refer to 3.3.4.2 Functional Movement Screen in Chapter 3.

4.3.4 Data Analysis

Once data collection was complete but prior to data scoring, inter- and intrarater reliability was established on 10% of the data set. That is, two rater's double coded 10% of the data to determine intrarater reliability, and both rater's coded the same 10% of data to determine interrater reliability (Logan, Barnett, Goodway, & Stodden, 2017). The two principal investigators were required to reach a minimum of 95% interrater agreement for all ten FMS and seven FMS™. The FMS and FMS™ data sets were analysed using SPSS version 20.0 for Windows. Participants with any missing data as a result of incomplete camera angle footage or otherwise were subsequently omitted from the data set and analyses. Descriptive statistics and frequencies for FMS and FMS™ at the skill and composite score levels were calculated. Age-related differences in overall and individual FMS/FMS™ performances were analysed using one-way analysis of variance (ANOVA), or the Kruskal–Wallis test in the case of non-parametric data. Chi-square tests for independence identified if any movement-based differences by school year group existed while effect sizes, based on

Cramer's V, were classified as small = 0.07, medium = 0.17 or large = 0.29. Statistical significance was set at $p < 0.05$.

4.4 Results

Of the participants, 108 were male (59.7%) and 73 were female (40.3%); 79 adolescents were in year one (43.6%), 43 adolescents were in year two (23.8%) and 59 adolescents were in year three (32.6%). The mean age of the participants was 14.42 ± 0.98 years (age range: 12.31 – 16.41 years old). The associated age-related sample provides the opportunity to compare and contrast the mastery levels of adolescents across three year groups. The results will be presented below separately for FMS and the FMS™.

4.4.1 Fundamental Movement Skills

No participant, of those with full FMS data (n = 181), displayed a complete mastery level across all ten skills. The mean overall composite score was 68.72 (± 7.54), out of a possible total of 84. The highest skill performance was the catch, with 86.6% of the total sample achieving complete mastery. The poorest performance was for the horizontal jump, where only 14.8% of all students achieved complete mastery. The percentage of students who displayed complete mastery in each of the ten FMS, differentiated by school year group, is shown in Figure 4.1, while the proportion of males and females in each school year group who completely mastered each behavioural skill component across all ten FMS is shown in Table 4.1.

Across school year groups, a Kruskal–Wallis Test revealed a statistically significant ($p = 0.002$) effect for FMS data, with a progressive decline observed in the object control subset from first through to third year. A series of chi-square tests for independence were also conducted to determine the associations between school year group and FMS. Significant associations in the horizontal jump (p = 0.040) and the skip (p = 0.003) were found with the former showing a progressive decline and the later a progressive improvement from first through to third year. A particularly large effect size (0.431) was found for the object control subset (p = 0.002), and the individual skills of the dribble (p = 0.012) and the throw (p = 0.001), with both skills showing a progressive decline from the first through to the third year.

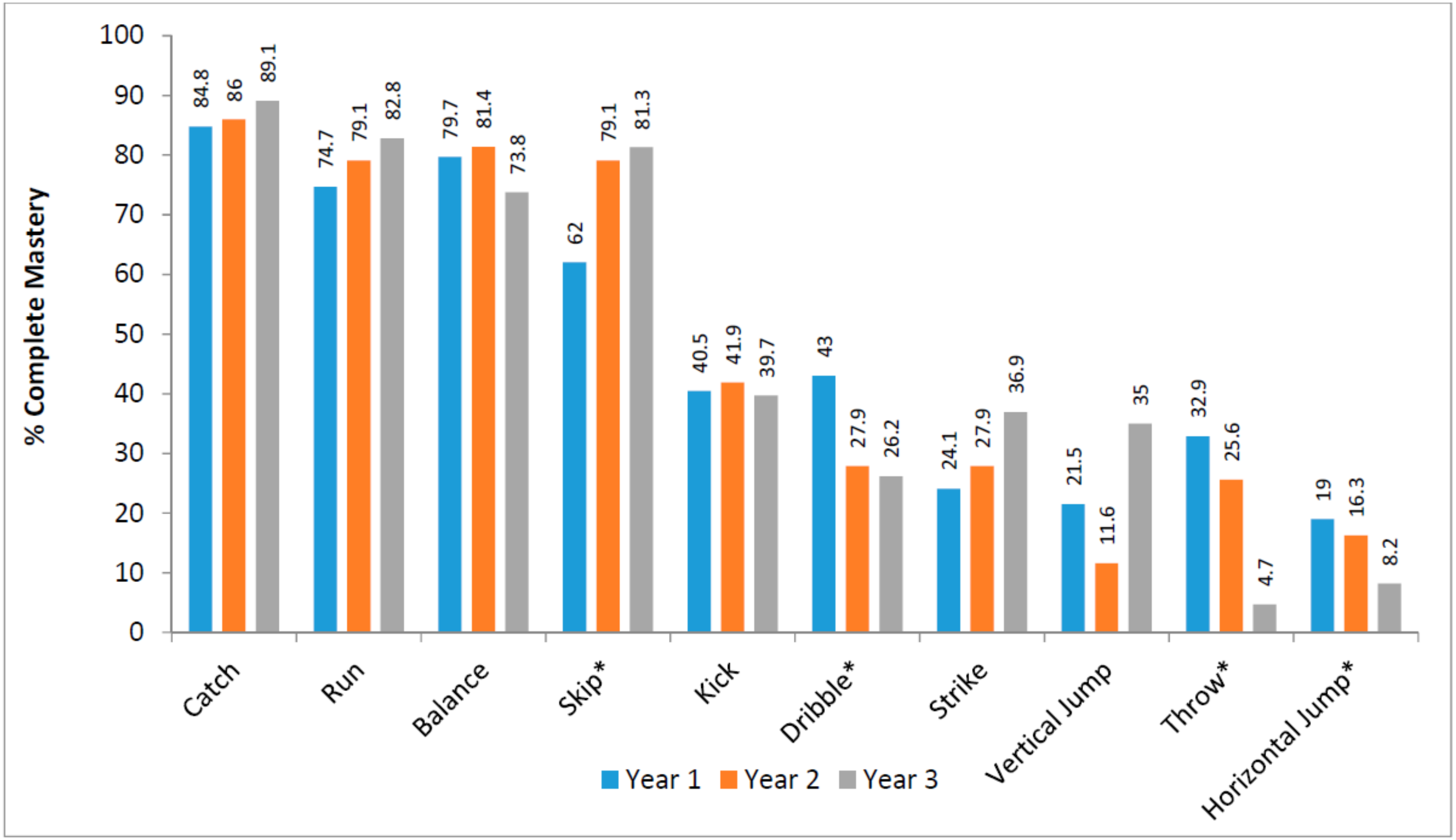

Figure 4.1: Percentage mastery of fundamental movement skills (FMS) by school year group.

[*$p \leq 0.05$]

Table 4.1: Proportion (%) of males and females in each school year group who correctly performed each component of each fundamental movement skill (FMS).

FMS Component	Males			Females		
	Year 1 (n = 46)	Year 2 (n = 28)	Year 3 (n = 34)	Year 1 (n = 33)	Year 2 (n = 15)	Year 3 (n = 25)
Catch						
(1) Preparation phase where hands are in front of the body and elbows are flexed.	93.5	96.4	91.4	97.0	100	100
(2) Arms extend while reaching for the ball as it arrives.	91.3	78.6	85.7	93.9	100	100
(3) Ball is caught be hands only.	97.8	85.7	80.0	87.9	100	100
Run						
(1) Arms move in opposition to legs, elbows bent.	91.3	89.3	91.7	81.8	86.7	89.3
(2) Brief period where both feet are off the ground.	100	100	100	100	100	100
(3) Narrow foot placement landing on heel or toe.	97.8	100	97.2	97.0	100	100
(4) Non-support leg bent approximately 90 degrees.	82.6	89.3	88.9	87.9	80.0	96.4
Balance						
(1) Support leg still, foot flat on the ground.	100	100	97.1	100	100	100
(2) Non-support leg bent, not touching the support leg.	93.5	89.3	94.3	84.8	100	92.3
(3) Head stable, eyes focused forward.	97.8	92.9	68.6	100	100	96.2
(4) Trunk stable and upright.	89.1	92.9	94.3	100	93.3	100
(5) No excessive arm movements.	87.0	85.7	94.3	84.8	93.3	100
Skip						
(1) A rhythmical repetition of the step-hop on alternate feet.	89.1	100	94.4	93.9	100	100
(2) Foot of non-support leg carried near surface during the hop phase.	93.5	100	94.4	93.9	100	100
(3) Arms alternately moving in opposition to legs at about the waist level.	60.9	75.0	86.1	69.7	86.7	78.6
Kick						
(1) Rapid continuous approach to the ball.	60.9	64.3	55.6	33.3	20.0	40.7
(2) An elongated stride or leap immediately prior to ball contact.	100	96.4	91.7	81.8	66.7	66.7
(3) Non-kicking foot placed even with or slightly in back of the ball.	87.0	92.9	86.1	39.4	46.7	55.6
(4) Kicks ball with instep of preferred foot (shoelaces) or toe.	100	100	94.4	93.9	86.7	96.3
Dribble						
(1) Contacts ball with one hand at about the belt level.	63.0	32.1	42.9	36.4	60.0	34.6
(2) Pushes ball with fingertips (not a slap).	95.7	96.4	91.4	84.8	73.3	88.5
(3) Ball contacts surface in front of or to the outside of foot on preferred side.	87.0	71.4	62.9	87.9	86.7	46.2
(4) Maintains control of ball for four consecutive bounces without having to move the feet to retrieve it.	82.6	92.9	88.6	97.0	86.7	88.5

Strike						
(1) Dominant hand grips bat above non-dominant hand.	45.7	57.1	69.4	60.6	60.0	72.4
(2) Non-preferred side of body faces the imaginary tosser with feet parallel.	95.7	96.4	88.9	57.6	80.0	82.8
(3) Hip and shoulder rotation during swing.	100	100	100	87.9	60.0	86.2
(4) Transfers body weight to front foot.	73.9	71.4	86.1	60.6	40.0	51.7
(5) Bat contacts ball.	80.4	85.7	88.9	69.7	86.7	72.4
Vertical Jump						
(1) Eyes focused forward or upward throughout the jump.	63.0	60.7	67.6	75.8	53.3	76.9
(2) Crouch with knees bent and arms behind the body.	71.7	71.4	73.5	45.5	53.3	57.7
(3) Forceful forward and upward swing of the arms.	34.8	10.7	47.1	42.4	46.7	38.5
(4) Legs straighten in air.	95.7	92.9	97.1	87.9	100	96.2
(5) Land on balls of feet and bend knees to absorb landing.	87.0	92.9	100	97.0	100	100
(6) Controlled landing with ≤1 step any direction.	87.0	100	100	100	100	100
Throw						
(1) Wind-up is initiated with downward movement of hand/arm.	97.8	100	100	97.0	93.3	100
(2) Rotates hip and shoulder to a point where the non-throwing side faces the wall.	50.0	39.3	8.6	9.1	6.7	0
(3) Weight is transferred by stepping with the foot opposite the throwing hand.	71.7	71.4	37.1	51.5	26.7	17.2
(4) Follow-through beyond ball release diagonally across the body towards the non-preferred side.	84.8	92.9	57.1	51.5	20.0	34.5
Horizontal Jump						
(1) Preparatory movement includes flexion of both knees with arms extended behind body.	87.0	85.7	88.6	69.7	73.3	76.9
(2) Arms extend forcefully forward and upward reaching full extension above the head.	28.3	25.0	14.3	9.1	20.0	0
(3) Take off and land on both feet simultaneously.	84.8	89.3	97.1	87.9	93.3	80.8
(4) Arms thrust downward during landing.	89.1	92.9	85.7	69.7	66.7	61.5

4.4.2 Functional Movement Screen

No participant, of those with full FMS™ data (n = 152), achieved complete mastery across all seven tests (maximum score of three for all). The mean composite score was 14.05 ± 2.48 out of a possible total of 21. The percentage of students who displayed complete mastery in each of the seven screening measurements, differentiated by school year group, is shown in Figure 4.2, while the proportion of students in each school year group who completely mastered each component of all seven assessments of the FMS™ is shown in Table 4.2.

Across the school year groups, a one-way ANOVA found a statistically significant ($p = 0.048$) decline in the in-line lunge from first through to third year. A chi-square test for independence confirmed a significant association between the year group and the in-line lunge ($p = 0.012$), with a Cramer's V (0.196) indicating a small to medium effect size.

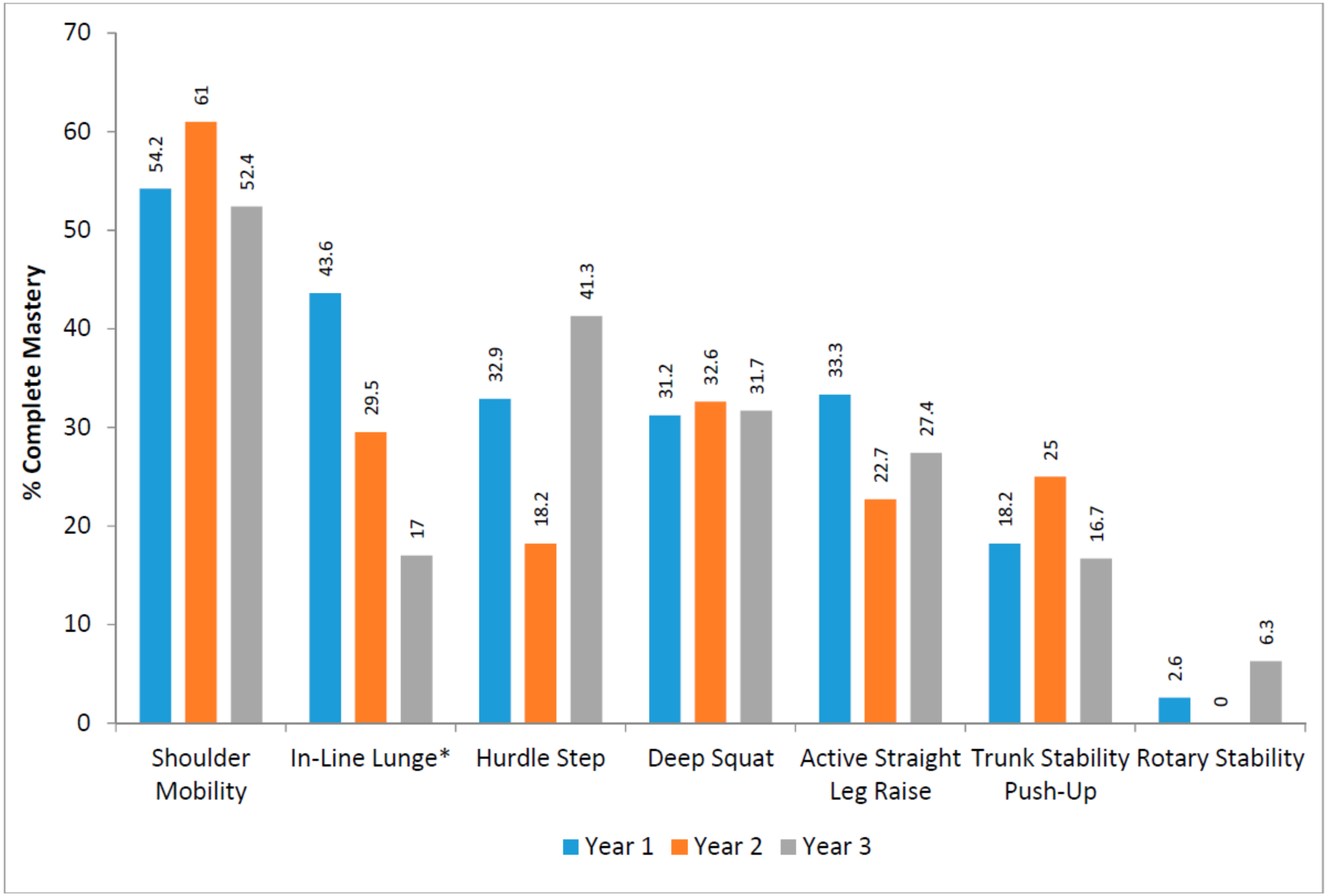

Figure 4.2: Percentage mastery of the Functional Movement Screen (FMS™) by school year group.

[* $p \leq 0.05$]

Table 4.2: Proportion (%) of participants in each school year group who correctly performed each component of the Functional Movement Screen (FMS™).

FMS™ Component	Year 1 (n = 68)		Year 2 (n = 41)		Year 3 (n = 43)	
Active Straight Leg Raise	**L**	**R**	**L**	**R**	**L**	**R**
(1) Knee on floor remains in contact with (i.e., touching) the board.	62.7	53.3	61.4	59.1	66.1	69.4
(2) Leg on floor does not externally rotate at the hip.	85.3	89.3	86.4	95.3	91.9	93.5
Deep Squat	-		-		-	
(1) Dowel maximally pressed overhead and aligned over feet. Note lumbar flexion.	77.9		81.4		76.7	
(2) Toes point forward.	75.3		86		88.3	
(3) Knees aligned over feet and knees do not go passed the toe line.	72.7		81.4		78.3	
(4) Thighs break parallel with the floor on descent (i.e., femur below horizontal).	77.9		72.1		73.3	
Hurdle Step	**L**	**R**	**L**	**R**	**L**	**R**
(1) Hips, knees and ankles aligned.	53.2	53.2	40.9	29.5	46	57.1
(2) Maintains a stable torso with minimal to no movement in lumbar (i.e., lower) spine.	79.7	84.8	86.4	93.2	92.1	93.7
(3) Dowel and hurdle remain parallel.	84.8	89.9	97.7	97.7	96.8	98.4
(4) Foot and/or heel touches the floor while standing leg remains in extended position.	96.2	97.5	97.7	100	100	100
(5) No contact between foot and hurdle.	98.7	100	100	100	100	100
In-Line Lunge	**L**	**R**	**L**	**R**	**L**	**R**
(1) Dowel remains in contact with head, thoracic spine and sacrum.	69.2	67.9	65.9	54.5	31.7	36.2
(2) Dowel remains vertical.	70.5	69.2	77.3	65.9	55.6	55.3
(3) No torso movement (i.e., balance is maintained).	91	91	86.4	97.7	92.1	93.6
(4) Knee touches board behind heel of front foot.	85.9	85.9	95.5	93.2	63.5	72.3
(5) The front heel remains in contact with the board and the back heel touches board when returning to starting position.	70.5	66.7	68.2	72.7	69.8	76.6
Rotary Stability	**L**	**R**	**L**	**R**	**L**	**R**
(1) Ankles dorsiflexed (i.e., toes tucked under).	9.5	14.9	13.6	18.2	19	17.5
(2) Back remains flat (i.e., spine remains parallel to board).	81.1	86.5	84.1	81.8	87.3	82.5
Shoulder Mobility	**L**	**R**	**L**	**R**	**L**	**R**
(1) Does not walk hands towards each other (i.e., one single motion).	83.3	89.2	85.4	90.2	100	98.4
(2) Head remains in neutral position.	76.4	77	76.9	79.5	93.7	92.1
Trunk Stability Push-Up	-		-		-	
(1) Body lifts as a unit with no lag in lumbar (i.e., lower) spine when performing the push-up (i.e., chest and stomach come off the floor at the same instance).	24.7		31.8		25	
(2) Ankles are dorsiflexed in both the preparatory and performance phases of the movement.	42.9		47.7		45	

4.5 Discussion

The aim of this study was to generate an overall perspective of movement during the initial three years (Junior Cycle) of post-primary education. This will serve to heighten the reader's understanding of the trends in movement proficiency. To the authors' knowledge, this is the first study of its kind to combine both fundamental and functional movement assessment in an adolescent population. The cross-sectional results highlight that a large proportion of adolescent youth are lacking both fundamental and functional movement skill proficiency. Specifically, no participant demonstrated overall mastery across the range of selected FMS and/or the FMS™, irrespective of the associated school-age year group breakdown. Irish adolescent youth may therefore be engaging in sport-specific skills, without learning the correct technique for the execution of basic skills and movement patterns (O'Brien et al., 2016a). This has potentially serious long-term consequences as it has been identified that keeping adolescents active has a greater impact on adult activity, as tracking improves with age (Lunn, Kelly, & Fitzpatrick, 2013).

Failure to develop proficient forms of fundamental movement has direct consequences for an individual's ability to perform task-specific skills at the specialized movement phase (Gallahue et al., 2012). The cohort assessed in this study ranged in age from 12 to 16 years, and therefore have the potential to be moving from the application to lifelong utilization stages of motor development within the aforementioned specialized movement phase (Gallahue & Ozmun, 2006). However, overall skill execution is low amongst the selected cohort of adolescent youth. These findings support the most recent motor development literature within Ireland (Belton et al., 2014; O'Brien et al., 2016a), suggesting that a 'proficiency barrier' (Seefeldt,

1980) may exist, in which the acquisition of sport-specific skills may be hampered by not developing an initial base of mature skills during the fundamental movement phase of development (Gallahue & Ozmun, 2006). The transition from one phase of development to another depends on the application of proficient patterns of movement to a wide variety of movement skills (Gallahue et al., 2012). Many adolescents lag in their movement capabilities because of limited opportunities to regular practice, poor or absent instruction, and little or no encouragement, albeit a person may still be cognitively and affectively ready to advance to the specialized movement skill phase of development (Gallahue et al., 2012). Interestingly, these overall low FMS findings are in line with most recent research carried out on adolescents in a different region of Ireland, which found that adolescents aged between 12 and 13 years entering their first year of post-primary PE did not display proficiency across nine basic movement skills (O'Brien et al., 2016a).

The three poorest performed skills across school year group are the overarm throw, vertical and horizontal jump. Mastering proficient throwing and jumping fundamental movements requires considerable muscular strength and power (Haywood & Getchell, 2009). It might seem plausible, therefore, as children move through adolescence that these particular skills would improve, in tandem with physiological muscular strength gains. The opposite is true, however, in this study with significant age-related declines observed in both throwing and jumping-related movements. Similar findings were observed in relation to poor levels of mastery in the vertical and horizontal jumps in a previous study amongst an adolescent cohort in Ireland (O'Brien et al., 2016a), albeit in contrast to these findings, a study in Australia (using mastery and near mastery (MNM)) found that over 80% of adolescents, irrespective of gender, had reached MNM performance in the vertical jump (Barnett et al., 2010). A possible explanation for the findings in the present study could be that to develop muscular strength, children and adolescents need to be physically active and provided with the opportunities to engage in outdoor play (Fjørtoft, 2001). It is well-established that the targeted adolescent population are becoming less physically active (Hoehner et al., 2008; Wang, Monteiro, & Popkin, 2002). Another plausible explanation for this trend is that too much emphasis is being placed on competitive participation at an early age, potentially leading to a later demise of mature motor development during adolescence. Evidence would not suggest that competition should be abandoned, but that more opportunities be made available and greater emphasis placed on the development of efficient and effective movement (Booth et al., 1999; Gallahue et al., 2012).

Similar to the low levels of FMS proficiency observed in the present study, overall sports-related functional movement patterns were low amongst participants, which is consistent with other previously published functional movement adolescent literature (Abraham et al., 2015; Paszkewicz, McCarty, & van Lunen, 2013; Portas, Parkin, Roberts, & Batterham, 2016). Overall, the mean composite FMS™ raw score for this study was 14.05 (out of a possible 21), which is similar, albeit slightly lower than the mean values reported by Abraham et al., (2015) on 1005 mixed-gender adolescents in India.

Interestingly, the in-line lunge was the only functional movement that showed a significant decline from first through to third year; the pattern that was evident for many of the FMS. This screening measurement assesses hip and ankle mobility and stability, quadriceps flexibility and knee stability (Cook, Burton, Hoogenboom, & Voight, 2014). Furthermore, the in-line lunge movement pattern is a component of deceleration and directional change, produced in exercise, activity and sport (Cook, 2010). Although poor performance during this movement can be the result of several factors, further analysis at a behavioural component level identified limitations in the thoracic spine region. In fact, 67% of participants in their first year of post-primary school were able to keep the dowel in contact with their head, thoracic spine and sacrum on the right side of the body; this figure fell to 54.5% in second year, and 36.2% in third year. Similarly, on the left side of the body, the decline across school year groups was equally apparent. These findings are further magnified when we compare the observed low findings of the overarm throw across the varying school year groups. Evidence suggests that efficient throwing is very often a result of properly timed weight shifting from the back foot to the front foot (Cook, 2010). This linear power transition turns into rotational power when the wave of energy generated in the lower body reaches the upper body, creating a throw (Cook, 2010). Further evidence would also suggest that as adolescents progress through their schooling years, prolonged periods of sitting in preparation for impending state examinations may be having a negative effect on postural stabilization.

Ultimately, the assessment of FMS and FMS™, as measured in the present cross-sectional study, provides a more robust evidence base for the potential development of an adolescent movement-based intervention. Indeed, creating a change in PA behaviour and movement skill proficiency during adolescence requires a multi-faceted approach (Bremer & Lloyd, 2014; O'Brien, Belton, & Issartel, 2015), with the necessity of creating developmentally appropriate activities (Barnett et al., 2010; Lai, Costigan, Stodden, Salmon, & Barnett, 2014; Logan, Robinson, Wilson, & Lucas, 2012; Morgan et al., 2013; Robinson et al., 2015) that positively impact movement proficiency. The availability of successful evidence-based programmes targeting motor development, particularly in the early childhood and pre-pubescent literature, has paved the way for the implementation of other FMS movement-oriented interventions to address the identified needs within specific populations (Barnett et al., 2013; Mitchell et al., 2013; O'Brien, Issartel, & Belton, 2013; van Beurden et al., 2003). Indeed, actual movement skills are one of the few modifiable risk factors for the prevention of poor health outcomes (Bremer & Cairney, 2016), and therefore promoting movement skill proficiency is integral to a holistic view of development (Barnett et al., 2016). Furthermore, previous research informed data on functional movement, as measured by the FMS™, suggests that structured interventions lead to positive movement-based outcomes (Kiesel, Plisky, & Butler, 2009), although the most effective ways to develop these movement patterns in Irish adolescent youth is yet to be elucidated. Movement interventions must consist of planned movement activities that are developmentally and instructionally appropriate (Logan et al., 2012). There does not appear to be a ceiling effect for both FMS and FMS™ from the current data presented, which necessitates the importance of adolescent intervention implementation for movement.

It is intended that these cross-sectional findings will help inform the design and development of a larger, movement-oriented intervention, at a later stage. Schools and PE are key potential vehicles for the promotion and provision of movement-based opportunities (Barnett et al., 2013; Belton et al., 2014). There is considerable data to suggest that the prescription of FMS programmes during PE may significantly enhance movement skill proficiency (Kalaja, Jaakkola, Liukkonen, & Digelidis, 2012; Martin, Rudisill, & Hastie, 2009; Mitchell et al., 2013; O'Brien et al., 2013). Essentially, the PE environment is a key opportunity to intervene because of access to children and adolescents, that is, for the purpose of improving movement skill proficiency in Ireland (O'Brien et al., 2013). Pedagogical factors such as adequate time set aside to practice the skill, optimal equipment-to-student ratios, specific skill instruction, and effective feedback and encouragement should also be standard practice in the teaching and learning process (Okely & Booth, 2004). It is hoped that through increased emphasis in schools and the wider educational environment, children may develop these movement skills and patterns for heightened PA participation through their lives (Okely & Booth, 2004).

A potential limitation of this research is the cross-sectional nature of the study, while the convenience sample of adolescents in this study was limited to just two post-primary schools in one Irish city. Primary areas for future research should therefore use a longitudinal design to provide more insight into how and why fundamental and functional movement may regress with age. Age in the current study was classified using the year of enrolment in school, and not biological age, and therefore any potential findings cannot be generalised to other adolescent populations. Further studies, including larger cross-sectional studies and controlled trials, are required to extend the evidence base and determine whether FMS and FMS™ proficiency change over time, or throughout maturation without intervention, or if movement proficiency changes in response to standardized intervention programs (Stobierski, Fayson, Minthorn, Valovich McLeod, & Welch, 2015).

4.6 Conclusions

Whilst further research is warranted, it appears that school year group is significantly associated with the mastery of movement skills and patterns. The results from the current study, particularly the significant decline apparent in certain skills and patterns, suggest that developing a specifically tailored movement-oriented intervention would be a strategic step towards improving the overall low levels of adolescent fundamental and functional movement proficiency.

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Author Contributions

The leading author Diarmuid Lester collected the data, analysed the findings, and wrote the paper. Wesley O'Brien helped with the assistance of collecting data, supporting the data analysis, and helped with the writing of the paper. Finally, Bronagh McGrane, Sarahjane Belton, Michael Duncan and Fiona Chambers served as external collaborators, specifically contributing to the writing of the paper.

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4.8 Link Section

The first two studies (chapters 3 and 4) presented in this thesis refer to the cross-sectional data, which investigated the gender and age-related differences in FMS and functional movement among a mixed-gender cohort of post-primary Irish adolescent youth aged 12-16 years old. The overall objective of these chapters was to provide context for the development of a multi-component, school-based, motor competence intervention (Project FLAME).

Chapter 3, the first study in this thesis, gathered cross-sectional data on Irish adolescent youth (N = 219; mean age: 14.45 ± 0.96 years), differentiated by gender, specifically in order to inform the development of a school-based, motor competence intervention. Chapter 4 was a particularly novel examination of the cross-sectional data (N = 181; mean age: 14.42 ± 0.98 years), specifically the prevalence of mastery of movement skills and patterns across the first three years (Junior Cycle) of post-primary (secondary school) education in Ireland. This study presented a distinctive examination of FMS and functional movement at the behavioural component level, differentiated by school year group, whereby weaknesses within performance across movements were identified.

Essentially, the assessment of FMS and FMS™, including the analysis of these constructs at a behavioural component level, provided a more robust evidence base for the potential development of an adolescent motor competence intervention. Understanding the trends in motor competence by gender and age provides practitioners with valuable information to implement instructional and intervention strategies.

The Project FLAME intervention was subsequently implemented in November 2018 (following the completion of baseline data collection). Further details outlining the specific structure of the Project FLAME intervention will be discussed in chapter 5. Specifically, the Project FLAME intervention was guided by the literature and underpinned by the developmental model of motor competence (Robinson et al., 2015; Stodden et al., 2008) as a theoretical framework. In this next chapter, the components of the Project FLAME intervention will be outlined, described and discussed.

Chapter 5

Rationale and study protocol for the Project FLAME non-randomized controlled trial: A multi-component, school-based, motor competence intervention for adolescent youth

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5.1 Abstract

Background: Adolescents in Ireland and other countries are failing to reach basic levels of fundamental movement skills (FMS) and functional movement. Schools and the engagement of relevant stakeholders, particularly qualified Physical Education (PE) specialist teachers, are key vehicles for the provision of movement-based opportunities in youth. The purpose of this paper is to report the rationale and study protocol design of Project FLAME (Fundamental and Functional Literacy for Activity and Movement Efficiency), a multi-component, school-based motor competence intervention for adolescent youth in Ireland.

Methods/Design: A sample of 363 participants (56% male, mean age: 14.04 ± 0.89 years old) were recruited from three mixed-gender, suburban schools (two intervention; one control), and using a non-randomized controlled trial design, a 13-week consecutive Project FLAME intervention was implemented. This whole-school, weekly delivered multi-component approach to FMS and functional movement involved the following pillars: i) specialist PE teacher component consisting of 15 to 20 minutes within the students' allocated weekly PE lesson(s), ii) kinaesthetic classroom component delivered by non-specialist PE teachers whereby a series of seven movement breaks, each of 3 minutes duration, ran concurrent to the PE component of the intervention, iii) student component and iv) digital literacy component.

Discussion: The Project FLAME intervention is the first of its kind in Ireland simultaneously targeting the improvement of FMS and functional movement for adolescents in school settings. This paper provides a detailed descriptive account and insight into the four major components of the Project FLAME intervention, providing a contextual overview of this multi-component intervention. The reported rationale and study protocol design offers a feasible, targeted whole-school approach, incorporating a number of novel strategies for increasing motor competence, including the concurrent involvement of specialist PE, and non-specialist PE teachers.

Keywords: fundamental movement skills; functional movement screen; physical education; school-based intervention; whole-school approach

5.2 Introduction

Lack of physical activity (PA) participation among children and adolescents is a global phenomenon, and it has been identified as a matter of urgency, in order to combat the alarmingly low levels of worldwide PA participation (Guthold, Cowan, Autenrieth, Kann, & Riley, 2010). For example, Ireland's largest nationally representative research on childhood PA surveillance, entitled the 'Children's Sports Participation and Physical Activity' (CSPPA) study (Woods et al., 2018), recently observed that only 10% of adolescents (aged 12 to 18 years old) reach the recommended levels of PA for health (60 minutes of moderate-to-vigorous physical activity (MVPA) per day).

Fundamental movement skills (FMS) are the basic observable building blocks or precursor patterns of the more specialised, complex movement skills required to successfully participate in organised and non-organised games, sports and recreational activities (Clark & Metcalfe, 2002; Hands, 2012). Examples exhibited during sport, exercise and PA include running, hopping, skipping (locomotor), throwing, catching, kicking (object control), balancing, twisting and dodging (stability) (Department of Education Victoria, 1996; Goodway, Ozmun, & Gallahue, 2020). These skills attempt to cover the most representative or salient skills that, if mastered, will give children the best possible chance to successfully and persistently participate in a range of health-enhancing physical activities (Barnett et al., 2016). Children have the developmental potential to master most FMS by six years of age (Goodway et al., 2020) while other research has revealed that many children demonstrate mature patterns of motor skill development (e.g., FMS) by the age of ten (Ulrich, 2000).

Competence in a range of FMS is considered to be the foundation for an active lifestyle (Goodway et al., 2020; Lubans et al., 2012). Belton et al. (2014) highlight that the cross-sectional evidence for FMS competence has accelerated, with positive FMS associations found for total PA (Fisher et al., 2005), MVPA (Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006), skill-specific PA (Raudsepp & Päll, 2006) and organised PA (Okely, Booth, & Patterson, 2001) in youth. The strategic advice outlined in the former CSPPA study (Woods, Tannehill, Quinlan, Moyna, & Walsh, 2010), outlined that in order to achieve increases in youth PA participation levels, the development and promotion of FMS was needed. Current trends in Ireland indicate that children and youth are insufficiently skilled to benefit their current and future health (Belton et al., 2014). Indeed, many children entering adolescence have not yet acquired these basic movement skills (Hardy, Barnett, Espinel, & Okely, 2013), and most recent research confirms that Irish adolescent youth are not performing FMS to their expected developmental capabilities (Lester et al. 2017; O'Brien et al. 2018). Furthermore, it is plausible that Irish adolescent youth may be engaging in sport-specific skills, without learning the correct technique for the execution of FMS (O'Brien, Belton, & Issartel, 2016a).

While movement skills are recognised as one of the few modifiable risk factors for the prevention of poor health outcomes (Bremer & Cairney, 2016), lack of competence in movement skills may be compounded by other intrinsic risk factors such as muscle asymmetry, core stability deficiencies, and postural defects (Morton, Barton, Rice, & Morrissey, 2014). This domain of movement is known as functional movement, and is an important consideration for motor development, as it relates to an individual's mobility and quality of life (Edelson, Mathias, Fulgoni, &

Karagounis, 2016). The ability to execute different movements with correct technique should enable more effective force transmission within dynamic tasks and aid in postural stability and body alignment within open skilled activities (Lloyd et al., 2015). Functional movement is often measured by the globally established FMS™ (Cook, Burton, Fields, & Kiesel, 1998; Cook, Burton, & Hoogenboom, 2006b), a pre-participation evaluation tool that comprises a series of movements designed to simultaneously assess multiple domains of function including range of motion, stability, balance and the overall quality of movement patterns (Letafatkar, Hadadnezhad, Shojaedin, & Mohamadi, 2014; O'Connor, Deuster, Davis, Pappas, & Knapik, 2011; Wright et al., 2016). International research, including most recent Irish data, has consistently highlighted deficits in functional movement patterns in adolescent populations (Abraham, Sannasi, and Nair 2015; Anderson, Neumann, and Huxel Bliven 2015; Lester et al. 2017; O'Brien et al. 2018; Paszkewicz, McCarty, and van Lunen 2013; Portas et al. 2016).

The promotion of motor competence is an integral strategy in holistically viewing children's development (Barnett et al., 2016; Estevan & Barnett, 2018; Robinson et al., 2015). Researchers are becoming increasingly more aware that perceived motor competence or an individual's perceived ability to perform a skill (Babic et al., 2014; Estevan & Barnett, 2018; Seabra et al., 2013), has a potential effect on PA participation, so much so that actual and perceived motor competence have been previously reported to be inextricably linked (Barnett, Morgan, van Beurden, Ball, & Lubans, 2011). Accurate estimations of motor competence are suggested to trigger an individual's motivation to improve skills in order to be more successful (De Meester et al., 2016). Most recent research has found that adolescents have high levels of perceived fundamental and functional movement competence (De Meester et al. 2016; McGrane et al. 2016; McGrane, Powell, et al. 2018; O'Brien et al. 2018).

Movement interventions consist of planned activities that are developmentally and instructionally appropriate (Logan, Robinson, Wilson, & Lucas, 2012). Following a systematic review of nineteen interventions, Morgan et al. (2013) highlighted that the most successful programmes aimed at increasing motor competence utilised PE specialists, or highly trained classroom teachers, as well as providing developmentally appropriate activities. School employees, therefore, have an important role to play in the promotion of PA in the school setting (Hills, Dengel, & Lubans, 2015). PE teachers are highly influential and become the most significant change agents, because they provide instructional support and skill-learning opportunities during class time (Chan, Ha, & Ng, 2016; Chan, Ha, Ng, & Lubans, 2019; Rink, Hall, & Williams, 2010). As role models for students, PE teachers contribute to the development of a movement culture as well as the overall culture for PA at a school (Hills et al., 2015). As such, PE represents an ideal opportunity for students to develop competence, confidence, and foster lifelong motivation to be physically active (Chan et al., 2019; Dudley, Okely, Pearson, & Cotton, 2011). Although schools are well positioned to provide all students with opportunities to be physically active, it is clear that many schools are not achieving their potential (Hills et al., 2015). This highlights a need to move to change the school culture from an individual climate, where PE teachers traditionally worked in isolation for childhood PA promotion and motor development, to a more cooperative culture, whereby all teachers are seen as facilitators of this process (Duncan and Birch 2012; Duncan, Stanley, and Leddington Wright 2013; Eyre et al. 2016; McMullen et al. 2015; NCCA 2017). The importance of these programme champions and school leaders was recently highlighted as a motivating factor associated with effective teacher planning for structured classroom PA-based lessons (Dyrstad, Kvalø, Alstveit, & Skage, 2018).

Schools are a favourable setting for interventions aimed at improving adolescent motor competence (goal-directed movement), specifically as they reach a majority of potential participants, and it is also well-known that adolescents spend a large portion of their waking hours in the school setting (Hankonen et al., 2016). In particular, teaching movement skills in a developmentally and instructionally appropriate climate have been found to improve actual and perceived motor competence in younger children (Robinson & Goodway, 2009; Robinson, Rudisill, & Goodway, 2009), both of which have been identified as important variables for future PA participation in adolescents (Barnett, Morgan, van Beurden, & Beard, 2008). These improvements in actual and perceived motor competence have been reported to be substantial when teachers are supported to teach FMS (Lander, Brown, Barnett, & Telford, 2015; Lander, Eather, Morgan, Salmon, & Barnett, 2017; Mitchell et al., 2013; van Beurden et al., 2003), and this has also been re-affirmed in most recent Irish PE curricula at national level (Belton, O'Brien, McGann, & Issartel, 2019). Motor competence improvements through the school context involve the long-term professional development of teachers, the employment of specialist PE consultants (Belton, Issartel, et al. 2019; Hardy et al. 2012; NCCA 2017), and a 'bottom up' approach in helping to make FMS a curricular priority within taught classes (Belton et al., 2014).

There is now considerable data to suggest that the prescription of FMS programmes during PE (Kalaja, Jaakkola, Liukkonen, & Digelidis, 2012; Martin, Rudisill, & Hastie, 2009; McGrane, Belton, Fairclough, Powell, & Issartel, 2018; Mitchell et al., 2013; O'Brien, Issartel, & Belton, 2013) may significantly enhance motor competence. The CSPPA study (Woods et al., 2018), suggests that an FMS programme, for example, not aligned to any one sport or activity, but whose purpose is to develop overall skills and abilities common to all sports and activities is needed in Ireland. Movement oriented programmes that involve quality instruction, feedback, adequate skill practice opportunity, and fun activities from qualified personnel have been identified as promising approaches in previous systematic review and meta-analysis data (Morgan et al., 2013). Meta-analyses from twenty-two studies (including six RCTs, thirteen quasi-experimental trials and three pre-post trials) describing nineteen interventions in primary/elementary schools revealed significant intervention effects for overall gross, locomotor, and object control domains (Morgan et al., 2013). These data provide evidence that school-based, teacher supported interventions may be an effective way to improve motor competence (Kalaja et al., 2012; Utesch & Bardid, 2019).

FMS and functional movement patterns have been identified as key mediators for positively influencing children's PA participation, and cardiorespiratory fitness (Cohen, Morgan, Plotnikoff, Barnett, & Lubans, 2015; Duncan & Stanley, 2012; Holfelder & Schott, 2014; Lubans, Foster, & Biddle, 2008; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Understanding and considering both fundamental and functional movement as two elements within a continuum, may provide a more rounded approach to motor development by reflecting more accurately the skills and movements inherent in a wider range of sports, and games in which adolescents participate (Coker, 2018; Lester et al., 2017). The purpose of this paper is to describe the rationale and study protocol design used in the development and implementation of Project FLAME (Fundamental and Functional Movement for Activity and Movement Efficiency), specifically the four pillars associated with the intervention.

5.3 Methods/Design

5.3.1 Study Design

The Project FLAME intervention will be evaluated using a non-randomized controlled trial (RCT) (Figure 5.1). A non-randomization procedure based on school location was chosen for practical reasons, and to prevent contamination, as the intervention is delivered in the class group setting. The intervention was delivered at the school level, and within that, then at class level, so it was not possible to have intervention and control groups within the same school. The 13-week multi-component, motor competence intervention targeted a convenience sample of adolescents in Years One to Three (aged 12–16 years old) of post-primary school, typically referred to as the 'Junior Cycle' period in Ireland. Data collection measurements were conducted at pre-test baseline [October-November 2017], and repeated at post-test [March 2018]. The design, conduct and reporting of this cluster non-RCT has followed the Transparent Reporting of Evaluations with Non-randomized Designs (TREND) guidelines for group trials (Des Jarlais, Lyles, & Crepaz, 2004). These guidelines emphasise the reporting of theories used and descriptions of intervention and comparison conditions, research design, and methods of adjusting for possible biases in evaluation studies that use non-randomized designs (Des Jarlais et al., 2004). Ethical approval was provided by the Social Research Ethics Committee (SREC) of University College Cork in March 2016.

The schools selected for participation were requested to either; a) deliver the Project FLAME intervention through their existing PE, and subject-specific classroom-based curricula (intervention group) or b) continue to follow their existing PE, and subject-specific classroom-based curricula, without any additional resources, or instructional support (control group). The Project FLAME intervention was offered to both intervention schools as a means of complementing regular school-based and subject-specific curricula, in an attempt to ensure that all students normally participated in school-based activities, regardless of whether they had given consent for the specific data collection study measurements. All students from the intervention classes in Years One to Three were, therefore, eligible to participate in the programme, provided they did not have a pre-existing injury, or medical condition that would exclude them from their regularly timetabled PE class.

5.3.2 Recruitment, Setting and Participants

Three mixed-gender, non-fee-paying post-primary schools (two intervention; one control) from the same sub-urban area in County Cork, Ireland, were invited to participate. All schools were located in close proximity to the lead researcher, while one of the two intervention schools was selected due to its classification as a Delivering Equality of Opportunity in Schools (DEIS) school by the Government of

Ireland, students of which are at greatest risk of educational disadvantage (Department of Education and Skills 2017).

Prior to the commencement of this school-based study, the lead researcher visited the Principal/Deputy Principal of each participating school, where a full outline of the data collection, and intervention processes were provided. Subsequent to the granted approval from school Principals, a briefing session was convened to introduce the Project FLAME programme to the participating PE teachers. Six PE teachers were recruited and retained overall, and when broken down by sample size, three PE teachers from each of the two intervention schools participated in the research.

Information sheets and consent forms were then distributed to the selected class groups for their intended participation. Informed parental/guardian consent, and child assent were the requirements for eligible participation in this study. Each school and participant was informed that their participation in the study was entirely voluntary, and that they were free to withdraw from the study at any time.

A sample of 442 students from the three schools were initially invited to participate in this study, with consent provided by 363 participants (mean age: 14.04 ± 0.89 years) (82% of total sample). Of the participants, 204 were male (56%) and 159 were female (44%); 118 participants were in Year One (33%), 120 participants were in Year Two (33%) and 125 participants were in Year Three (34%). In terms of the final sample, 266 participants (73%) were in the intervention group, while 97 participants (27%) were in the control group.

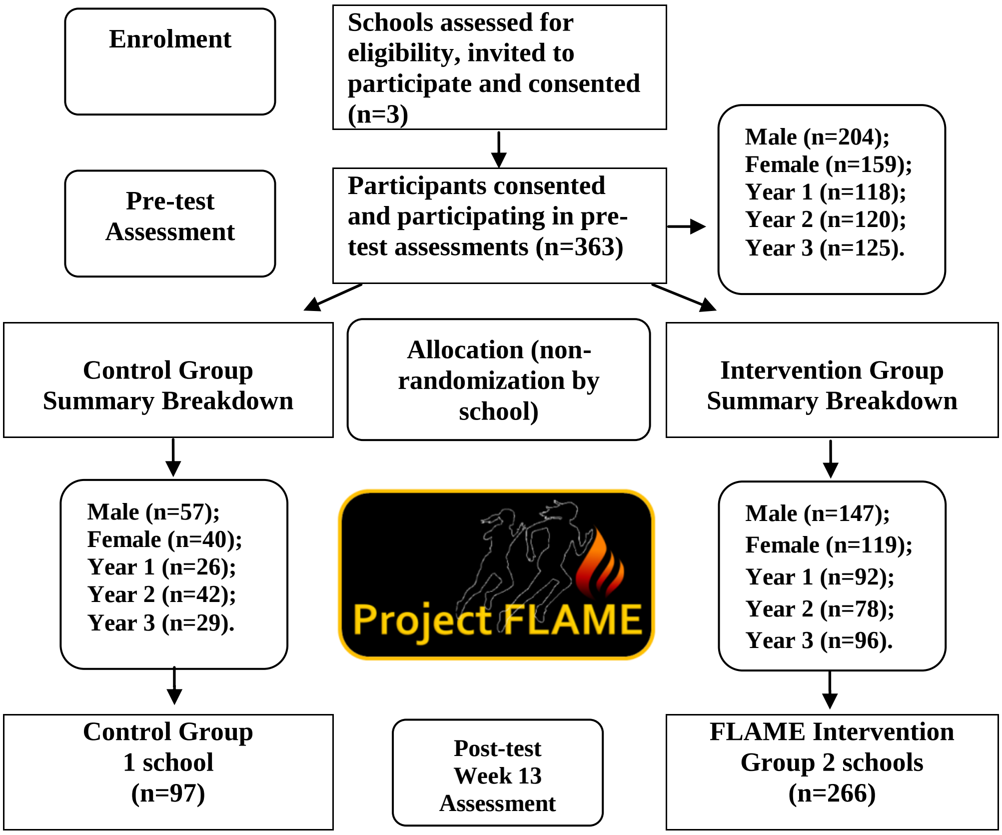

Figure 5.1: Flow of participants through the research process.

5.3.3 Proof-of-Concept Intervention Feasibility Trial

In April 2017, a short proof-of-concept intervention feasibility trial for Project FLAME was conducted over a four week period in a single school, with three PE teachers involved, and three class groups of students (n = 78), spread across years 1 to 3. The purpose of this trial was to demonstrate the acceptability of the initially designed Project FLAME PE intervention concept in a naturalistic setting, prior to the non-RCT rollout, from the perspective of the PE teachers only.

As part of the Project FLAME training protocol, PE teachers were encouraged to adopt a stations-based approach as part of the feasibility trial, as well as the development of a mastery motivational climate (Martin et al., 2009). It was intended that the PE teachers would demonstrate the stations for each Project FLAME lesson, with at least two levels of task difficulty per station, while the PE teachers were also expected to highlight the research-informed external cues, as related to particular aspects of the movements. PE teachers were provided with a suite of YouTube links, which they could share with students, as appropriate, to support the teaching and learning process. Students were then invited and encouraged to move freely throughout the stations during PE class time. This autonomous learning environment allowed students the choice in which stations to visit, the length of time which they wanted to spend at each station, and the level of task difficulty the students selected. The PE teacher actively supervised the students, and was encouraged to talk with individual students through regular feedback regarding effort or progress.

Although no formal PE teacher training was provided at this ‘proof of concept’ research phase, the lead researcher did meet with the three PE intervention teachers collectively, in advance of the trial, and provided them with a plan for the four weeks comprising of materials and resources necessary to facilitate the delivery of the lessons. The stations-based approach was discussed along with the use of movement cards, external cues and the integration of the digital resources.

This feasibility trial, which included qualitative data collection via a focus group interview with the three PE teachers, was conducted upon completion of the trial. This focus group interview was recorded with a Dictaphone, and transcribed verbatim by the lead researcher. The constant comparative method was then used to analyse the focus group data (Merriam, 1998), a process that involved manually highlighting and comparing the emergent themes (Braun and Clarke 2006; Clarke and Braun 2013).

Following thematic analysis, two keys themes emerged from the focus group interviews. These themes were clustered around ‘materials and resources’ and ‘effectiveness and suitability’. In terms of guiding the non-RCT intervention rollout, the first key theme that emerged from the data related to materials and resources. The feedback from the PE teachers involved in this short trial was positive, in that the PE teachers identified the Project FLAME movement cards for PE as *‘very clear and the progressions were good’*. The use of external cues within the movement cards were also perceived to be an effective pedagogical tool, particularly the *‘simple ones that they could remember’* and *‘because a lot of them are beside the picture, it makes it clear for them’*. In relation to the digital resources provided by the research team, findings were somewhat mixed, with one PE teacher highlighting that they *‘didn’t use the YouTube videos. We don’t really have the projector facilities to do that but they did like them’*. It was, however, acknowledged by another PE teacher that *‘if they’re able to use them, I think they would be excellent’*. The research team used this feedback to further enhance the quality of the movement cards, specifically by linking the external cues with particular aspects of each movement. The digital resources were also further developed by transferring the video links into more user-friendly quick response (QR) codes.

The second key theme was the effectiveness and suitability of the suggested stations-based approach. It was evident from the focus group that the originally planned station-based approach for Project FLAME lacked practical usability for the PE teachers, with one participant citing that *‘it would be easier to focus on one skill or movement per session’*. Furthermore, one PE teacher highlighted that *‘it got a bit manic going in between the different stations’*, while another confirmed that *‘it was a bit difficult to see if they were doing each station correctly’*. Taking this into account, it was decided to focus on one skill or movement pattern per lesson going forward for the non-RCT phase of Project FLAME. Ultimately, the focus group interview undertaken with the PE teachers as part of this proof-of-concept intervention feasibility trial identified two important themes relating to the PE component of the intervention.

It is worth noting that other items were also mentioned by individual teachers as part of the focus group data, *‘progress monitoring of students’* for example, but these items were in isolation, and were not considered as additional themes. This focus group data led to further improvements, and an upgraded version of the intervention (reported below) being developed in advance of the non-RCT phase of the study.

5.4 Intervention

5.4.1 Theory

Project FLAME is a 13-week multi-component, motor competence intervention for post-primary schools (Figure 5.2), underpinned by the developmental model of motor competence (Robinson et al., 2015; Stodden et al., 2008). At the heart of this model is a reciprocal and developmentally dynamic relationship between motor competence, and PA participation in children and youth (Stodden et al., 2008). Essentially, the development of motor competence is a primary underlying mechanism that promotes engagement in PA, and aligns to the measurement protocol of this study. By developing higher levels of motor competence, participants will in turn have a greater motor repertoire to engage in various physical activities, sports, and games (Stodden et al., 2008). Aligned with this directional developmental model, the emergent relationship between the development of motor competence and PA over time is suggested to be mediated by other factors, including perceived motor skill competence, physical fitness, and obesity (Stodden et al., 2008). As children transition from childhood to adolescence, an obvious and significant 'PA divide' will occur between low-skilled and inactive children, who also perceive themselves as poorly skilled, and will not enjoy participation in activities where they understand that they will not be successful, in comparison to their higher skilled, and more active peers, who find PA rewarding and fun (Robinson et al., 2015; Stodden et al., 2008). As a result of higher levels of cognitive development in adolescence, the mediating role of perceived motor skill competence on PA is magnified, as it more closely approximates actual motor skill competence (Harter, 1999; Robinson et al., 2015; Stodden et al., 2008). This Project FLAME intervention focuses on the proposed developmental model pathway between actual motor competence and PA, as mediated by perceived motor competence, our identified secondary outcome.

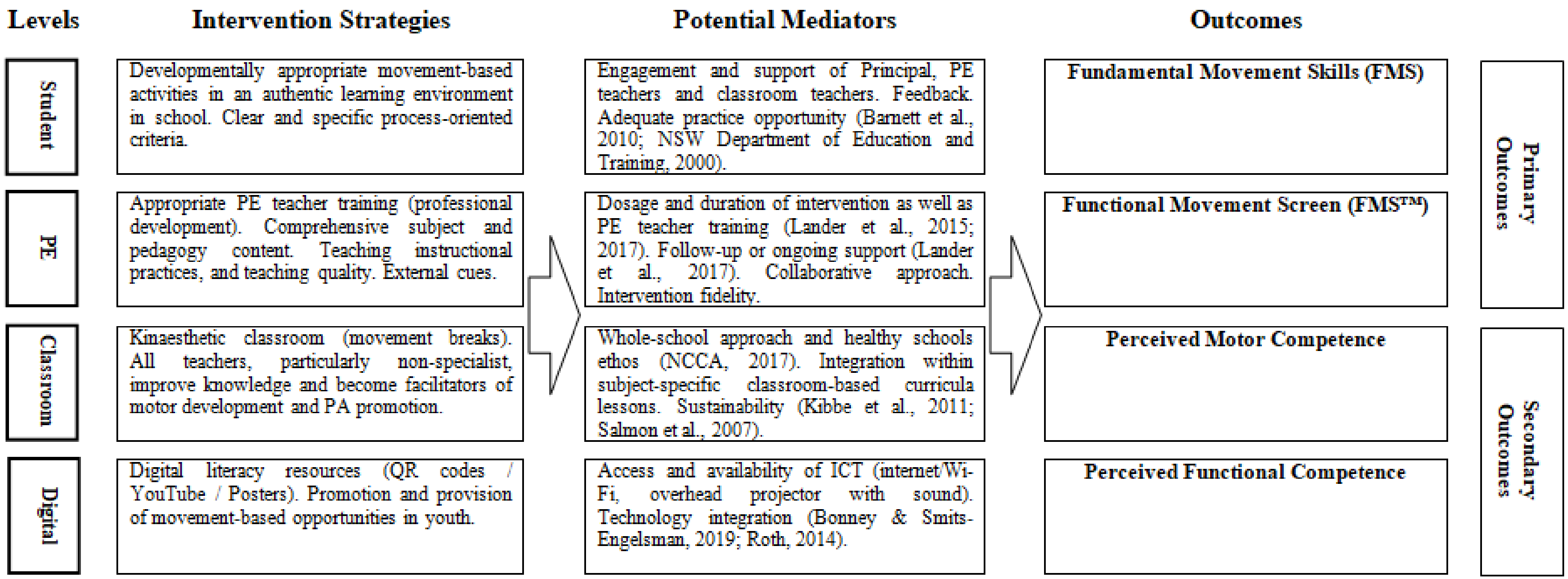

Figure 5.2: Project FLAME intervention components, potential mediators and measurement outcomes.

[*ICT* = information and communications technology; *PE* = physical education; *PA* = physical activity; *QR* = quick response]

5.4.2 Project FLAME Components

The Project FLAME whole-school intervention consisted of four major components (Figure 5.2), specifically the i) specialist PE teacher component, ii) kinaesthetic classroom component, iii) student component and iv) digital literacy component.

5.4.2.1 Specialist PE Teacher Component

The PE component of the intervention involved deliberate practice of a prescribed fundamental movement skill, or functional movement pattern for a duration of 15 to 20 minutes within the students' allocated weekly PE lesson(s) (typically 80 minutes). While PE teachers were encouraged to embed the prescribed Project FLAME movement at any appropriate point in each PE lesson, the inclusion of this movement at the lesson's beginning was suggested as the most effective. Although the prescribed fundamental movement skill, or functional movement pattern may have been completely independent of the PE teacher's originally intended lesson content as per the PE curriculum at Junior Cycle, the objective of this intervention component was to integrate the pedagogically assigned movement cards within the lesson, and in doing so, reinforce learning, while building and refining the adolescent movement base.

The aim for the PE teacher was to have the students master a skill or movement pattern, rather than simply experience it (Chan et al., 2016). Specific teaching strategies were therefore integral to the overall success of this intervention, with pedagogical emphasis placed on the use of external movement-based cues for augmenting adolescent learning. An example of an external cue focusing on the use of the arms in the vertical jump would be the ‘Mexican wave’, whereby the participant moves from a crouched position to a forceful forward and upward swinging position using the arms, as identified in this type of movement action. Numerous studies have provided converging evidence that an external focus of attention speeds up the learning process, thereby enabling participants to achieve a higher level of expertise sooner (Wulf, 2007). Both movement outcome and form can be enhanced in complex skill learning by providing learners with relatively simple external focus instructions (Wulf, 2013).

Furthermore, PE teachers were encouraged to provide students with the opportunity to practice their FMS and functional movement patterns through the use of varying equipment, such as bean bags, and different-sized balls for catching and throwing. By encouraging a wide range of equipment within Project FLAME, the complexity of the skill learning is varied (Griggs, 2012). Following a review of the facilities available in the respective schools, all suggested pedagogical activities were designed to be suitable for indoor and outdoor teaching environments, requiring minimal space and equipment. Finally, assessment for student learning (AfL) was intertwined within the Project FLAME teaching process, and was not considered separate to teaching (Chan et al., 2016). PE teachers were, therefore, required as part of Project FLAME to use effective questioning techniques, observations, and implement quality oral feedback on the success criteria (or performance criteria).

In summary, a PE teacher had successfully implemented Project FLAME if they taught a 15- to 20-minute segment of motor competence in every PE lesson, with a pedagogical emphasis on the use of external movement-based cues for augmenting adolescent learning. PE teachers were also encouraged to use a variety of equipment to meet the varying needs of students along with the provision of quality oral feedback on the success criteria of the prescribed Project FLAME movement.

5.4.2.2 Kinaesthetic Classroom Component

The kinaesthetic classroom aspect of the intervention targeted the non-specialist PE teachers of the school, challenging those to become facilitators of movement, as well as active role models for young people, by promoting PA opportunities in school, outside of PE class. The lead researchers designed a series of seven movement breaks, each of 3 minutes duration, and these ran concurrent to the PE component of the intervention, with one kinaesthetic classroom activity encouraged per week in the school.

Movement breaks were uploaded to YouTube in advance of the intervention commencement, and the associated link was emailed to all 49 teachers by the lead researcher each Sunday, prior to the start of the school week. The email addresses were provided to the research team by the respective school Principals. The YouTube link was also sent via a messaging application – ‘WhatsApp’ – to the teachers who provided the research team with their personal phone numbers. It is important to note that the classrooms in both intervention schools were equipped with sufficient information technology (IT) facilities, including Wi-Fi and overhead projectors, and the prescribed weekly movement breaks were also suitable for classrooms with limited space and no equipment.

The focus of each movement break was to reinforce the movement-based learning from the PE environment, with emphasis on the quality, rather than the quantity of movement (Logan, Barnett, Goodway, & Stodden, 2017). Students followed the audio-visual cues in the YouTube video, which was intended to be projected onto the interactive whiteboard, or screen. Each movement break began with an introduction and demonstration of a movement skill or movement pattern at a basic level, for example, the vertical jump, at which point students were given the opportunity to practice this movement in tandem with the video on screen. To ensure that all activities were developmentally appropriate for students, the second part of the movement break included a higher progressive level of motor competence, for example, executing a vertical jump while turning in the air and landing on a specified time on a clock face, as directed on screen. The role of the non-specialist PE teacher was to organise the learning environment to ensure maximum participation from the class.

The lead researcher served as the external contact person with the intervention schools, but had no direct involvement with the non-specialist PE teachers on the implementation of movement breaks as part of the kinaesthetic classroom intervention component. According to Dyrstad et al. (2018), teachers have different levels of motivation for changing their teaching methods and daily routines, and it was, therefore, decided to keep movement breaks unscheduled, of short duration, and at the discretion of the individual teacher for implementation.

5.4.2.3 Student Component

The student is the core component of the Project FLAME intervention, and as a result, all components of the intervention were designed for and with the student in mind, specifically in order to support his/her development. Competition has previously been identified as one of the predominant barriers to adolescents fully participating in PE (Bauer, Yang, & Austin, 2004), and for these reasons, the PE component of the intervention consisted of choice for the students, and was primarily cooperative, rather than competitive (Belton et al., 2014). Each pedagogically assigned movement card comprised of PE tasks at a basic level, and at a higher progressive level (one minimum) to ensure activities were developmentally appropriate for students (Martin et al., 2009).

Each skill card identified the required standards of movement in a clear and explicit manner. This was achieved using specific behavioural success criteria, and based on responses from the focus group interviews (conducted following the proof-of-concept intervention feasibility trial), simplified pedagogical language was used. The success criteria were developmental in nature, providing students with a trajectory to measure and progressively achieve competence in each movement, whilst at the same time fostering independence in learning movement skills (Chan, Ha, and Ng 2016; Clarke 2008).

The way in which the specialist PE teacher chose to use the task cards in the lesson was at their own discretion and very much context specific to the environment. In some cases, the PE teacher may have chosen to use the task card to support their delivery of the movement skill or movement pattern, including demonstrations and associated progressions, while orally describing to their students the specific success criteria. In other cases, the teacher may have chosen to distribute the task cards to each student or groups of students, as appropriate.

5.4.2.4 Digital Literacy Component

Project FLAME encourages students to learn and practice movements both inside and outside of the classroom. The inclusion of technology within the PE environment has the potential to promote effective teaching and learning (Chan et al., 2016). In support of the hard copy resource cards, the research team also recorded video clips of the intervention activities in practice. The purpose of this was to facilitate the integration of technology as part of the instructional processes, by providing a virtual learning environment (VLE) that was fruitfully interactive. With the further development of these video links into more user-friendly QR codes following the completion of the proof-of-concept feasibility trial, PE teachers were then able to show their students the respective movements in action on a smart phone or tablet, by scanning the corresponding QR code to each relevant activity. PE teachers were provided with posters to facilitate and encourage the integration of the QR codes in their lessons. Each associated video clip lasted between 20 to 40 seconds in length to ensure maximum time on task for students.

It was envisaged that the digital component would provide a platform for further self-regulated practice, and learning outside of the school context by allowing students to make improvements independently. Students were provided with weekly handouts with all QR codes pertaining to the fundamental movement skill or functional movement pattern, as per the focus of the PE component of the lesson.

In conclusion, the Project FLAME intervention constituted four major components, as described above, and all components were required to be implemented as part of this school-based intervention. The PE teacher had direct autonomy with the PE component, as well as guiding the student component of the intervention. The kinaesthetic classroom component of the intervention, however, was at the discretion of the non-specialist PE teachers of the school, and the implementation of this component will have differed invariably from school to school, and class to class. Similarly, although the PE teacher had control over the integration of the digital component during direct PE lesson contact time with students, each individual student's motivation for further self-regulated practice outside of the school environment will again have varied from person to person.

5.4.3 Continuing Professional Development Teacher Training

Two continuing professional development (CPD) workshops were provided to the three PE teachers in each of the two intervention schools (n = 6, total number of PE teachers) and attendance at both of these workshops was required in order to deliver the Project FLAME intervention (See Table 5.1). The first two-hour training workshop took place one week prior to the intervention roll out, where the lead researcher, also a practicing PE teacher, visited both schools independently. The research team decided on this protocol to ensure PE teachers felt comfortable in their own school environment, specifically as this was where the intervention would be implemented in practice. Furthermore, it was hoped that by adopting this method, PE teachers would fully engage in practical sessions and group discussions, while also raising any critically informative issues or concerns.

Table 5.1: Continuous professional development (CPD) for PE teachers and targeted constructs in the Project FLAME intervention.

Goals of the CPD	**Activities of the CPD and programme content**	**Teaching principles, pedagogies and key features of the behaviour change strategies used during CPD**	**Assessment of CPD**
The research team delivered two professional development workshops for PE teachers. The first two-hour workshop took place one week prior to the intervention roll out, where the lead researcher visited both schools independently. The second CPD workshop consisted of a one-hour collective mid-programme review meeting and further training for the PE teachers in both intervention schools. The CPD workshops focussed on improving mastery of movement, and provided support for effective teaching methods. The stated objectives of the CPD workshops was for the PE teachers to; **1)** refresh and upskill their knowledge in the teaching and	During the initial CPD workshop, a detailed intervention plan and checklist was provided to the PE teachers, in conjunction with the associated teacher resource manual. This Project FLAME resource manual included an illustrated practice handbook of pedagogical cards, comprising of fundamental movement skills, and functional movement patterns. In each of these pedagogical cards, visually illustrative images, and instructional information about the key observable components of each movement were provided, as well as access to video links in the form of QR codes. During the CPD workshops, PE teachers were instructed about the testing protocol and the performance criteria of each of the selected movements. The lead researcher demonstrated the standards required.	Learning objectives and success criteria shared so that students understand what they are trying to learn, and what is expected of them. Both teachers and students are focused on the criteria that the movements will be assessed against. Clear and specific success criteria for students enabled them to progressively achieve a level of mastery, be successful and develop self-competence. A high level of movement and physically active learning time using simple, enjoyable and convenient activities. Quality instructions using external cues. Tasks and instructions modified to increase the opportunity to experience success. Tasks incorporate multiple challenge	Project FLAME intervention checklist was used to determine teachers' adherence to prescribed lessons. Social support from colleagues (i.e. PE teachers and (deputy) principals) in the intervention school and external support from the lead researchers provided motivational reinforcement and encouragement. Teachers met collectively at the mid-point of the intervention to share feedback and establish their views on the programme, as well as how they used the resources provided. Further support and training was provided via face-to face interaction if needed. Ongoing contact with research team to discuss lesson implementation. PE teachers involved in the intervention also received regular support from the Project FLAME research team,

assessment of motor competence (both FMS and functional movement). **2)** highlight common errors associated with learning specific skills and movement patterns, by enabling PE teachers to provide students with the appropriate feedback. **3)** share pedagogical teaching techniques, and practical ideas to facilitate the development of student movement within Project FLAME.	Practical sessions and group discussions were led by the lead researcher to examine how to teach the selected movements using external cues and aligned with the existing performance criteria. Emphasis on quality instruction and practice coupled with constructive oral feedback to improve mastery of movement. Use of technology as part of the instructional process to provide a learning environment that was colourful, engaging, and interactive. With the QR Code video links, for example, teachers had the option to show their classes what the movement or activity looked like in action, or through a tablet or iPad.	levels, and give students an element of autonomy to select their own level of difficulty. Equipment is plentiful and developmentally appropriate. Appropriate oral feedback provided by the PE specialist teacher on effort, process and progress. Students' understanding checked through the effective use of questioning. Students encouraged to assess their own skill performances (for example, detect and correct their own errors) using the key observable components of each movement. Use of technology to make the teaching–learning process more meaningful. Distribution of printed and audiovisual educational materials (for example, handouts with QR codes) encouraged further self-practice outside of the school context by providing access to simple and fun activities to strengthen learning anywhere, anytime.	through a messaging application – 'WhatsApp' – for sharing, and answering questions.

The objectives of the CPD workshops was for the PE teachers to; i) refresh and upskill their knowledge in the teaching and assessment of FMS and functional movement patterns; ii) highlight common errors associated with learning specific skills and movement patterns, by enabling PE teachers to provide students with the appropriate feedback to refine and improve their respective competence levels and iii) share pedagogical teaching techniques, and practical ideas to facilitate the development of students within Project FLAME.

During the initial CPD workshop, a detailed intervention plan and checklist was provided to the PE teachers, in conjunction with the associated teacher resource manual. This Project FLAME resource manual included an illustrated practice handbook of pedagogical cards, comprising of FMS, and functional movement patterns. In each of these pedagogical cards, visually illustrative images, and instructional information about the key observable components of each movement were provided, as well as access to video links in the form of QR codes (Adkins, Wajciechowski, & Scantling, 2013; Baxter, McEntyre, & Woodruff, 2018; Shumack, Reilly, & Chamberlain, 2013). The second CPD workshop consisted of a one-hour collective mid-programme review meeting for both intervention schools, in order to provide further support via face-to face interaction, and allow all six PE teachers to share feedback about the intervention.

5.4.4 Data Collection

Pre-test (baseline), and post-intervention assessments were conducted by trained field staff at the study schools. Prior to the pre-test baseline phase of data collection, all twenty four field staff, who were undergraduate pre-service PE teachers, underwent a rigorous and robust 8-hour field researcher training workshop in order to gain competence in the measurement protocol associated with FMS and the FMS™. This involved an objective, criteria-informed process to ensure field staff were consistent in the administration and implementation of the movements. For consistency and accuracy, a protocol manual, which included specific instructions for conducting all assessments, was developed and used by research assistants (Lubans et al., 2012). A second, but shorter, 2-hour refresher field researcher training workshop was also conducted in advance of the post-intervention assessments. The same groups of field researchers re-assessed participants for both the FMS and the FMS™ (Coker, 2018). In terms of the research rigour associated with school-based measurements on adolescents, it is important to note that the lead researchers for this study are qualified post-primary specialist PE teachers, as recognised by the Teaching Council of Ireland. Furthermore, all researchers and field staff were appropriately vetted at national level to ensure compliant education standards, when working with children and youth.

Objective measurements were collected with participants in their class groups (maximum n = 30) during a 2-hour school visit, which typically coincided with a PE class, with a ratio of at least one trained field staff to every five students. It is important to note that the physical assessments, such as anthropometric characteristics (height and weight) were conducted by two members of the field staff (one male and one female) who were trained by the lead researcher prior to data collection. In order to ensure these measurements were completed in a sensitive and discreet manner, participants were assessed in a specific area of the sports hall, away from their peer group. Mass was measured to the nearest 0.1kg using a SECA calibrated heavy-duty scale, while height was measured to the nearest 0.1cm using a SECA Leicester portable height measure. Shoes were removed for both measures. Subjective self-report questionnaire measurements of the perceived motor competence variables were taken during a separate school visit in a computer lab, under the supervision of the lead researcher, using the online tool of 'Survey Monkey' for participant responses. All participants were assigned ID codes for anonymity purposes during data collection.

5.4.5 Primary outcomes

5.4.5.1 Fundamental Movement Skills

The following ten FMS were assessed: run, skip, horizontal jump and vertical jump (locomotor, maximum score of 34); two-handed strike, stationary dribble, catch, kick, overhand throw (object control, maximum score of 40) and balance (stability, maximum score of 10), which combined to give an overall gross motor skill competence raw score from 0–84. Process-oriented assessments of FMS were used in preference to product-oriented assessments, because they identify more accurately specific topographical aspects of the movement (Logan et al., 2017; Logan, Robinson, Rudisill, Wadsworth, & Morera, 2014; Ulrich, 2000). Each of the ten FMS were assessed in conjunction with the observable, behavioural components from three testing batteries, with established reliability and construct validity (Cools, De Martelaer, Samaey, & Andries, 2009; NSW Department of Education and Training, 2000; Ulrich, 2000), namely the Test of Gross Motor Development (TGMD) (Ulrich, 1985) (skip), TGMD-2 (Ulrich, 2000) (run, horizontal jump, two-handed strike, stationary dribble, catch, kick and overhand throw) and the Get Skilled: Get Active manual (NSW Department of Education and Training, 2000) (balance and vertical jump). These instruments were selected to give an objective measurement of gross motor skill competence across a range of skills, including those skills particularly relevant to the Irish sporting context and PE environment (O'Brien et al., 2016a; Woods et al., 2010). Prior to participant performance, one trained field staff member provided an accurate demonstration and instruction of the skill to be performed. Procedures outlined in the TGMD-2 examiner's manual (Ulrich, 2000) were closely adhered to within the assessment of the ten FMS. The TGMD-2 has been established as a reliable and valid assessment of motor competence in children and adolescents (Issartel et al., 2017; Ulrich, 2000). To ensure participant consistency within skill performance, no feedback, verbal or otherwise, from any of the trained field staff was given during the testing. Participants performed the skill on three occasions, including one familiarization practice, and two performance trials (Ulrich, 2000). The number of performance criterion varied from three to six across the range of selected FMS, and the two performance trials were added together to get the total for each skill score across the ten skills (O'Brien et al., 2016a).

Video cameras (3× Canon type Legria FS21 cameras; Canon Inc., Tokyo, Japan and 2× Apple iPads, Apple Inc., California, United States) were used to record each participant's performance, and execution of the required skill. The distance and camera angles were at all times consistent; specifically, to ensure that the complete body movement was captured (O'Brien et al., 2016a; O'Brien, Belton, & Issartel, 2016b). The use of video-recording is an important consideration in data collection, as it permits greater scrutiny, and therefore accuracy of measurement precision

(Okely & Booth, 2004). The behavioural components of each skill were assessed at a later date by the lead researchers.

5.4.5.2 Functional Movement Screen

All seven movement patterns within the FMS™ were assessed: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up and rotational stability (Cook et al., 1998). The FMS™ has a scoring range from 0 to 3 for each of the seven individual tests, with 3 being the optimum score (Cook, 2010). The test administration procedures, instructions and scoring process associated with the standardized version of the test (Cook, Burton, & Hoogenboom, 2006a; Cook et al., 2006b) were followed in order to ensure accuracy in scoring (Abraham et al., 2015; Bardenett et al., 2015). Normative values have been established for the FMS™ in adolescent school-aged children (N = 1005; 10 to 17 years old) (Abraham et al., 2015). Trained field staff utilised the pre-determined verbal instructions during testing. During data collection, each participant was again video-recorded, and given three attempts to perform the movement. On account of the video-recording set-up for data collection, it should be noted that the lead researchers scored the optimum trial stringently at a later date, and the total composite score (maximum of 21) was then calculated.

5.4.6 Secondary outcomes

5.4.6.1 Perceived Motor Competence

The physical self-confidence scale (McGrane et al., 2016) was used as an indicator to measure the perceived motor competence of participants' FMS. This scale was selected, as it is a reliable and valid instrument that assesses physical self-confidence in adolescents at a skill specific level. In other words, the instrument assesses the association between perceived FMS and actual FMS using a comparable scale (McGrane, Powell, et al., 2018). Within this physical self-confidence scale, participants were asked to rate their competence at performing 10 FMS, based on a Likert scale format of 1-10. A score of '1' indicated being not competent at all and a score of '10' indicated being very competent. As previously reported, this measurement tool has excellent test-retest reliability (r = 0.92) (McGrane et al., 2016), and excellent internal consistency, with a Cronbach's alpha coefficient of 0.94 (O'Brien et al., 2018). Furthermore, the scale demonstrates good content and concurrent validity (r = 0.72), when compared to the physical self-perception profile (Harter, 1985).

5.4.6.2 Perceived Functional Competence

A recently developed tool to assess perceived functional movement competence amongst an Irish adolescent population was used as an indicator to measure participants perception of FMS™ competence (O'Brien et al., 2018). Again, participants were asked to rate their competence at performing the identified 7 FMS™ tasks, based on a Likert scale format of 1-10, as part of this functional movement competence scale. A score of '1' indicated being not competent at all and a score of '10' indicated being very competent. This is the first instrument that has been developed to assess perceived functional movement competence in adolescents. As the FMS™ tasks are non-sport specific, a visual image alongside the question is provided (Barnett, Ridgers, Zask, & Salmon, 2015; Barnett et al., 2016), in support of a previously validated pictorial instrument for assessing FMS perceived competence. It has been previously reported that the perceived functional movement competence scale has good test-retest reliability, with coefficients for the 7 items ranging from 0.82 to 0.93, and excellent internal consistency, with a Cronbach's alpha coefficient of 0.92 (O'Brien et al., 2018).

5.5 Discussion

In this paper, the authors describe the rationale and study protocol for Project FLAME, an innovative, multi-component, school-based intervention targeting improvements in adolescent motor competence. This is the first study of its kind in Ireland targeting both actual and perceived levels of FMS and functional movement, as a means to counteract the steep decline in adolescent PA participation (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008).

It must be acknowledged that multiple enabling and disabling constraints are present across childhood and adolescence, which can influence a child's developmental trajectory in motor competence (Robinson et al., 2015). Once attained, the development and learning of motor competence across childhood and adolescence is associated with a relatively permanent change in behaviour (Robinson et al., 2015; Schmidt & Lee, 2005). In this instance, highly developed motor competence during adolescence has the potential to foster lifelong functional independence, quality of life (Robinson et al., 2015), and should be prioritised within health promotion interventions. The focused holistic approach for motor competence adopted in the current Project FLAME study is intended to facilitate this developmental pathway for adolescents.

The literature widely acknowledges that there is strong rationale for school-based programmes aimed at increasing FMS competence (Kalaja et al., 2012; Lubans et al., 2012; McGrane, Belton, et al., 2018; van Beurden et al., 2003), and more recently functional movement (Coker, 2018), particularly those delivered by qualified PE teachers, including the provision of professional learning opportunities (Cohen, Morgan, Plotnikoff, Barnett, et al., 2015; Mitchell et al., 2013; Morgan et al., 2013). If teachers receive well-designed and comprehensively integrated training, they can increase specifically targeted areas of student achievement (Armour, Quennerstedt, Chambers, & Makopoulou, 2017; Armour & Yelling, 2007; Lander et al., 2017). Welk (1999) previously recognised PE as an optimal vehicle for determining PA habits of youth, a component that is heavily integrated within the current Project FLAME intervention. The details described in this paper, including the rationale and study protocol design of the Project FLAME intervention may be beneficial to PE educators, or other researchers who are looking for novel strategies to holistically target motor competence in a school-based setting.

A systematic review and meta-analysis of FMS interventions among youth found that interventions on average offer between 8 hours and 195 hours of instruction, and run for 12 weeks (median) (Morgan et al., 2013). Although the majority of the interventions in this review related to primary schools, Project FLAME is similar in terms of timescale, however, the direct instruction time within PE is at the lower end, when compared to other interventions. It is envisaged that this lapse in direct PE instruction time, as facilitated by the specialist teacher within Project FLAME may be compensated for within other indirect instructional time opportunities embedded within the intervention, such as the kinaesthetic classroom and digital components. Sufficient practice opportunities are necessary to master skills, and to provide students with continuing attempts for more challenging tasks (Chan et al., 2016).

A novel aspect of the Project FLAME intervention is the kinaesthetic classroom component for adolescents, specifically the involvement of non-specialist PE teachers (i.e., classroom teachers) as part of a whole-school approach to the development of a movement culture. While the researchers did not formally collect data on the number of movement breaks implemented by each classroom teacher, this suggested intervention component reflected a move away from the traditional viewpoint of the PE teacher being the person in the school with sole responsibility for health promotion (McMullen et al. 2015; NCCA 2017). This shift in cultural focus is similar to other whole-school approaches targeting numeracy and literacy, whereby the sole responsibility no longer resides with the Mathematics and English teacher respectively (Department of Education and Skills 2011). A report released by the Centers for Disease Control and Prevention (CDC) in 2011 highlighted that schools have direct contact with children and youth for an average of 6 hours per day, and for up to 13 years, a period that reflects critical social, psychological, physical and intellectual development (CDC 2011). There may be an inherent need to transcend the subject of PE further within the broader school environment, specifically to prepare youth for a lifetime of PA engagement (Belton et al., 2014). Several programmes such as Project Energize (Mahar et al., 2006), Project Spraoi (Bolger et al., 2019), Take 10 (Kibbe et al., 2011), Physical Activity Across the Curriculum (Donnelly & Lambourne, 2011), Texas I-CAN (Bartholomew & Jowers, 2011; Grieco, Jowers, Errisuriz, & Bartholomew, 2016), and Active Smarter Kids

(Resaland et al., 2018) have introduced PA into the school learning environment in the primary school domain (Dyrstad et al., 2018), with encouraging findings emerging in relation to PA (Kibbe et al., 2011; Mahar et al., 2006), as well as other areas such as academic achievement (Centeio et al., 2018; Kibbe et al., 2011; Resaland et al., 2018).

Prior to the implementation of the non-RCT, the Project FLAME resources and intervention components were refined, as per the feedback received from the three PE teachers (proof-of-concept intervention feasibility trial), who each had one class group of students (n = 78). The purpose of this trial was to demonstrate the acceptability of the initially designed Project FLAME PE intervention concept in a naturalistic setting, from the perspective of the PE teachers only. This qualitative aspect of the research led to further improvements, and an upgraded version of the intervention being developed in advance of the non-RCT phase of the study. The PE component of Project FLAME helped ensure that all students were 'learning to move' and not only 'moving to learn' within PE (afPE 2015). While the overall adoption and implementation of intervention components take time (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015), the purpose of this component was to complement the existing pedagogical strategies of the PE teachers. The prescribed Project FLAME activities, specifically the use of the external cues, could be integrated at any appropriate point in each PE lesson (15- to 20-minutes), including for example, as part of a warm-up making this component feasible for PE teachers. The kinaesthetic classroom component of the intervention meanwhile typified the development of a movement culture using a whole-school approach. While this type of approach may not be embraced by all non-specialist PE teachers, many teachers are willing and capable of integrating movement breaks within their lessons while there is growing knowledge and indeed acceptance of the fact that all staff have an important role to play in the promotion of PA in the school setting (Hills et al., 2015). By diluting the level of competition in the PE component of the intervention, which has previously been identified as the predominant barrier to adolescents fully participating in PE (Bauer et al., 2004), the student component sought instead to provide quality and developmentally appropriate practice opportunities that would challenge each individual student (i.e., within a class group setting), to improve their respective level of motor competence. Research has confirmed that helping children practice FMS, for example, at home, outside of the school environment is also important (Chan et al., 2016). The digital component of Project FLAME provided students with unlimited access to all of the relevant movement-based activities of the intervention through the use of QR codes. The recent coronavirus (COVID-19) pandemic (Xu et al., 2020; Zhu & Chen, 2020) provided further justification and indeed magnification for the integration of the digital literacy component within Project FLAME, for example, and throughout the PE curriculum as a whole, such was the necessity for a virtual learning environment (VLE).

The strengths of this study include the study protocol design and the comprehensive multi-component approach to this adolescent motor competence intervention. Crucially, the strategies formulated in Project FLAME are replicable, relatively transferable to scale, and may provide a valuable school framework for understanding adolescent motor competence in practice. Other strengths of Project FLAME include the proof-of-concept intervention feasibility trial, as highlighted, that preceded and subsequently informed the larger non-RCT phase of the study.

Given that Project FLAME was implemented in an authentic or naturalistic whole-school setting and was delivered by school personnel, it was difficult to control the quality or indeed quantity at which each participant in the experimental group received the intervention. A notable limitation of the study, therefore, is the absence of intervention fidelity data collected. A lack of meaningful information surrounding the effectiveness of the teacher training, and broader CPD in general, is further evidence of the absence of intervention fidelity data collected. Acknowledging the study design strengths and limitations, the findings of the non-RCT will, however, determine if Project FLAME is a promising approach for enabling adolescent youth to improve their motor competence, and whether the programme can be delivered on a larger scale in post-primary schools.

5.6 Conclusion

This paper has reported the rationale and study protocol design for Project FLAME, a multi-component, school-based motor competence intervention for adolescent youth in Ireland. By providing a detailed descriptive account, as well as a critical review of the methods, this paper attempts to justify the decisions made in the development of the four major components of the Project FLAME intervention, namely the i) specialist PE teacher component, ii) kinaesthetic classroom component, iii) student component and iv) digital literacy component, all targeting motor competence in a holistic manner. The reported study protocol design offers a feasible, targeted whole-school approach to increasing motor competence, and by incorporating a number of novel strategies, the findings from the study may have important implications for the future teaching and learning of PE at post-primary level. Future research must examine the efficacy of this evidence-based intervention, prior to wider dissemination.

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Chapter 6

A school-based intervention to improve functional movement and fundamental movement skills in adolescent youth: Evaluating the effectiveness of Project FLAME

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6.1 Abstract

Background: School-based physical education (PE) interventions are considered to be an effective method for improving childhood and youth motor competence. This study aimed to evaluate the effectiveness of Project FLAME (Fundamental and Functional Literacy for Activity and Movement Efficiency), a multi-component, school-based PE intervention targeting improving fundamental movement skills (FMS) and functional movement in adolescent youth.

Methods: Using a non-randomized controlled trial, a sample of 363 participants (56% male, mean age: 14.04 $\pm$ 0.89 years old) were recruited from three mixed-gender, sub-urban schools (two intervention; one control) in Cork, Ireland, for baseline data collection, followed by a 13-week consecutive intervention roll out, and post-test data collection. The Project FLAME intervention included four major components, specifically the i) specialist PE teacher component, ii) kinaesthetic classroom component, iii) student component and iv) digital literacy component. Primary outcome measures evaluating the effectiveness of the Project FLAME intervention included the assessment of ten FMS (including locomotor and object control subsets), in conjunction with the observable, behavioural components from three established testing batteries (Test of Gross Motor Development (TGMD), TGMD-2, and the Get Skilled: Get Active manual), as well as the seven tests within the Functional Movement Screen (FMS™). Linear mixed models were used to analyse the effect of the intervention with two main effects, treatment and time, and their hypothesised interaction. Analyses were adjusted for participants' gender, age, grade and BMI score.

Results: The intervention group significantly improved in their locomotor (p = .001), object-control (p = .002), and overall gross FMS (p = .001), from pre- to post-intervention. Furthermore, significant intervention effects across time for locomotor score (p = .003) and overall gross FMS (p = .002) were observed, when compared with a control group. The observed effects were significant and positive for all participants in the intervention group, regardless of gender, age, grade, or BMI. The intervention group also significantly improved their overall FMS™ composite score (p = .001), however, a statistically significant treatment-time interaction effect was not found between groups (p = .981).

Discussion: Findings confirm that the Project FLAME multi-component, school-based intervention was successful at improving adolescent locomotor and overall gross FMS motor competence, when compared with a control group, resulting in significant treatment-time interactions. A whole-school approach, including a structured PE component, emphasising FMS and functional movement appears effective for developing motor competence in adolescent youth.

Keywords: motor competence; motor development; physical education; whole-school approach

6.2 Introduction

Fundamental movement skills (FMS) are the basic observable building blocks or precursor patterns of the more specialised, complex movement skills, required to successfully participate in organised and non-organised games, sports and recreational activities (Clark & Metcalfe, 2002; Hands, 2012). Examples exhibited during sport, exercise and physical activity (PA) include running, hopping, skipping (locomotor), throwing, catching, kicking (object control), balancing, twisting and dodging (stability) (Department of Education Victoria, 1996; Goodway, Ozmun, & Gallahue, 2020). Competence in a range of FMS is considered to be the foundation for an active lifestyle (Goodway et al., 2020; Lubans et al., 2012). Therefore, developing effective means for children and adolescents to develop FMS is key in creating positive trajectories for PA for life (Goodway & Robinson, 2015; Robinson et al., 2015).

Recent evidence and trends indicate lower FMS competence among children, when compared to normative data collected 20 years ago (Bardid, Huyben, et al., 2016; Bolger et al., 2019; Spessato, Gabbard, Valentini, & Rudisill, 2013). It is also evident that there is a lack of FMS competence among adolescents, with most recent research confirming that Irish adolescent youth are not performing FMS to their expected developmental capabilities (Lester et al., 2017; McGrane, Belton, Fairclough, Powell, & Issartel, 2018; O'Brien, Belton, & Issartel, 2016a; O'Brien, Duncan, Farmer, & Lester, 2018). Adolescence is a period consistently associated with a rapid decline in PA participation (Sutherland et al., 2013), while rising numbers of overweight and obese youth show preferences for sedentary activities (Khambalia, Dickinson, Hardy, Gill, & Baur, 2012; McGrane, Belton, et al., 2018;

World Health Organization, 2018). Research suggests that competence (Utesch & Bardid, 2019) in FMS may serve as a protective factor against the decline in PA participation, typically observed during adolescence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Belton, O'Brien, Meegan, Woods, & Issartel, 2014; McGrane, Belton, et al., 2018). It is crucial that interventions are developed to target this lag in adolescent motor competence (Cliff, Okely, Smith, & McKeen, 2009; McGrane, Belton, et al., 2018).

Whilst FMS are considered the building blocks for complex movements (Burns & Fu, 2018; Burton & Miller, 1998), functional movement, is another indicator of motor competence. Functional movement, defined as the ability to move the body with proper muscle and joint function (Coker, 2018), is based on the assumption that strength, flexibility, mobility and stability are prerequisites that underpin movement skill performance (Kraus, Schutz, Taylor, & Doyscher, 2014). For the adolescent youth population, it stands to reason that dysfunctional movements could impede motor development and performance (Coker, 2018). Functional movement is often measured by the globally established Functional Movement Screen (FMS™) (Cook, Burton, Fields, & Kiesel, 1998; Cook, Burton, & Hoogenboom, 2006), a pre-participation evaluation tool that comprises a series of movements designed to simultaneously assess multiple domains of function including range of motion, stability, balance and the overall quality of movement patterns (Letafatkar, Hadadnezhad, Shojaedin, & Mohamadi, 2014; O'Connor, Deuster, Davis, Pappas, & Knapik, 2011; Wright et al., 2016). International research, including recent Irish studies, have consistently highlighted deficits in functional movement patterns in adolescent populations (Abraham, Sannasi, and Nair 2015;

Anderson, Neumann, and Huxel Bliven 2015; Lester et al. 2017; O'Brien et al. 2018; Paszkewicz, McCarty, and van Lunen 2013; Portas et al. 2016). Thus, understanding or considering different aspects of motor competence such as fundamental and functional movement as two elements in a continuum of motor competence may provide a more insightful understanding within the motor development domain, by reflecting more accurately the skills and movements inherent in a wider range of sports and games in which adolescents participate (Rudd et al., 2016; Utesch, Bardid, Büsch, & Strauss, 2019).

Evidence indicates that motor competence is also positively associated with perceived motor competence and multiple aspects of health (i.e., PA, cardiorespiratory fitness, muscular strength, muscular endurance, and a healthy weight status) (Robinson et al., 2015). Perceived motor competence refers to an individual's perception of their actual movement capabilities (Babic et al., 2014; Estevan & Barnett, 2018; Harter, 1999; Robinson et al., 2015; Seabra et al., 2013), and plays a critical role in the continued development of movement across the lifespan (Hulteen, Morgan, Barnett, Stodden, & Lubans, 2018). Perceived motor competence has also been shown to mediate the association between motor competence and PA participation in adolescents (Barnett, Morgan, van Beurden, Ball, & Lubans, 2011; Barnett, Morgan, van Beurden, & Beard, 2008; Estevan & Barnett, 2018; Harter, 1982; Hulteen et al., 2018).

Correlations between actual and perceived motor competence in previous childhood studies appear inconsistent (Fliers et al., 2010; Khodaverdi, Bahram, Stodden, & Kazemnejad, 2016; Raudsepp & Liblik, 2002), suggesting a misalignment between children’s actual and perceived motor competence (Bardid, De Meester, et al., 2016). It is noted in the literature, however, that as children age their perception of their own motor competence will align better with their actual performance (Estevan & Barnett, 2018; Stodden et al., 2008). Most recent research indicates that adolescents do not underestimate their actual motor competence levels but conversely, overestimation is common, as adolescents tend to have high levels of perceived fundamental and functional motor competence (De Meester et al., 2016; McGrane, Belton, Powell, Woods, & Issartel, 2016; McGrane, Powell, Belton, & Issartel, 2018; O’Brien et al., 2018; Utesch, Dreiskämper, Naul, & Geukes, 2018). Overestimation of motor competence has been described as a favourable phenomenon by De Meester et al. (2016), as it might be positively associated with autonomous motivation for PE, and higher levels of engagement in PA and sports, especially among adolescents with low actual motor competence. Utesch et al. (2019) however describe realistic estimations as favourable for future PA engagement.

Schools are a favourable setting for interventions aimed at improving adolescent motor competence, specifically as they provide access to populations mostly at-risk (i.e., females, overweight/obese, those from low socioeconomic backgrounds and the inactive) (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015; Hardy, King, Espinel, Cosgrove, & Bauman, 2010; McGrane, Belton, et al., 2018). The logical avenue for addressing dysfunctional movements in adolescent youth is through PE (Coker, 2018), particularly in Ireland, as this subject is compulsory for all second level school students. That said, numerous school-based interventions have been evaluated and evidence suggests that multi-component interventions are more effective than subject-specific curriculum-only approaches (Cohen et al., 2015; Kriemler, Meyer, & Martin, 2011; Naul, Utesch, & Niehues, 2018). An intervention may provide children and adolescents with the necessary skills to facilitate PA and sport participation across the lifespan (Bolger et al., 2019). It is only through opportunities for quality practice of the skill, as well as through the provision of quality instructional practice during learning episodes however, that these skills can be developed and refined (Bolger et al., 2019; Goodway et al., 2020; Payne & Isaacs, 2002).

The primary aim of the current study (Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency) was to determine the effectiveness of a 13-week multi-component, teacher led intervention in changing adolescents' overall motor competence, when compared to a control-based condition. Additionally, the Project FLAME study aimed to evaluate changes in perceived motor competence over time.

6.3 Methods/Design

6.3.1 Recruitment, Setting and Participants

Three convenience sampled mixed-gender, non-fee-paying post-primary schools (two intervention; one control) from the same sub-urban area in County Cork, Ireland, were invited to participate. One of the two intervention schools was classified as a Delivering Equality of Opportunity in Schools (DEIS) school, by the Government of Ireland, students of which are at greatest risk of educational disadvantage (Department of Education and Skills 2017), while the other two schools were not. All three schools consented to participate.

Prior to the commencement of the study, the lead researcher visited the Principal/Deputy Principal of each participating school, where a full outline of the data collection, and intervention processes were provided. Subsequent to approval from school Principals, a briefing session was convened to introduce the Project FLAME programme to the participating PE teachers. Six PE teachers were recruited, with three PE teachers from each of the two intervention schools agreeing to participate in the research.

Information sheets and consent forms were then distributed to the selected class groups for their intended participation. Informed parent/guardian consent, and child assent were the requirements for eligible participation in this study. Each school and participant was informed that their participation in the study was entirely voluntary, and that they were free to withdraw from the study at any time. Ethical approval was provided by the Social Research Ethics Committee (SREC) of University College Cork in March 2016.

A sample of 442 students from the three schools were initially invited to participate in this study, with consent for data collection measurements provided by 363 participants (mean age: 14.04 $\pm$ 0.89 years) (82% of total sample). Of the participants, 204 were male (56%) and 159 were female (44%); 118 participants were in Year One (33%), 120 participants were in Year Two (33%) and 125 participants were in Year Three (34%). In terms of the final sample, 266 participants (73%) were in the intervention group, while 97 participants (27%) were in the control group.

6.3.2 Intervention

The rationale and study protocol design of the Project FLAME non-randomized controlled trial (RCT) has been reported in detail elsewhere. Briefly, Project FLAME is a 13-week multi-component, motor competence intervention for secondary schools, underpinned by the developmental model of motor competence (Robinson et al., 2015; Stodden et al., 2008). A non-randomization procedure, based on school location was chosen for practical reasons, and to prevent contamination, as the intervention was delivered in the class group setting. Specifically, the intervention was delivered at the school level, and within that, at the class level, so it was not possible to have intervention and control groups within the same school. The 13-week multi-component, motor competence intervention targeted a convenience sample of adolescents in Years One to Three (aged 12–16 years old) of second level school, typically referred to as the 'Junior Cycle' phase of education phase in Ireland. Data collection measurements were conducted at pre-test baseline [October-November 2017], and repeated at post-test [March 2018]. The design, conduct and reporting of this cluster non-RCT followed the Transparent Reporting of Evaluations with Non-randomized Designs (TREND) guidelines for group trials (Des Jarlais, Lyles, & Crepaz, 2004).

The schools selected for participation were requested to either; a) deliver the Project FLAME intervention through their existing PE, and subject-specific classroom-based curricula (intervention group) or b) continue to follow their existing PE, and subject-specific classroom-based curricula, without any additional resources, or instructional support (control group). The Project FLAME intervention was offered to both intervention schools as a means of complementing regular school-based and subject-specific curricula, in an attempt to ensure that all students normally participated in school-based activities, regardless of whether they had given consent for the specific data collection study measurements. All students from the intervention classes in Years One to Three were, therefore, eligible to participate in the programme, provided they did not have a pre-existing injury, or medical condition that would exclude them from their regularly timetabled PE class.

The Project FLAME intervention constituted four major components, specifically i) specialist PE teacher component consisting of 15 to 20 minutes within the students' allocated weekly PE lesson(s), and a specific focus on the use of external movement-based cues while fostering a mastery motivational climate in PE, ii) kinaesthetic classroom component delivered by non-specialist PE teachers whereby a series of seven movement breaks, each of 3 minutes duration, ran concurrent to the PE component of the intervention, iii) student component targeting developmentally appropriate activities and optimum challenge for student engagement, and iv) digital literacy component. While the intervention involved direct and indirect pedagogically informative strategies, the key features of this programme include quality instruction, focussed motor competence practice opportunities for students, the provision of usable resources to support teachers' ability in facilitating students movement vocabulary, the use of technology for heightening the process of teaching and learning, and the overall whole-school approach for the development of motor competence among adolescent youth.

Two continuing professional development (CPD) workshops were provided to the three PE teachers in each of the two intervention schools (N = 6, total number of PE teachers). The objectives of the CPD workshops was for the PE teachers to; i) refresh and upskill their knowledge in the teaching and assessment of FMS and functional movement patterns; ii) highlight common errors associated with learning specific skills and movement patterns, by enabling PE teachers to provide students with the appropriate feedback to refine and improve their respective motor competence levels, and; iii) share pedagogical teaching techniques, and practical ideas to facilitate the development of students within Project FLAME.

6.3.3 Data Collection

Please refer to 5.4.4 Data Collection in Chapter 5.

6.3.4 Primary outcomes

6.3.4.1 Fundamental Movement Skills

Please refer to 5.4.5.1 Fundamental Movement Skills in Chapter 5.

6.3.4.2 Functional Movement Screen

Please refer to 5.4.5.2 Functional Movement Screen in Chapter 5.

6.3.5 Secondary outcomes

6.3.5.1 Perceived Motor Competence

Please refer to 5.4.6.1 Perceived Motor Competence in Chapter 5.

6.3.5.2 Perceived Functional Competence

Please refer to 5.4.6.2 Perceived Functional Competence in Chapter 5.

6.3.6 Data Analysis

Once data collection was complete, but prior to data scoring, inter- and intra-rater reliability was established on 10% of the data set. That is, two raters double coded the same 10% of the data to determine intra-rater reliability (Logan, Barnett, Goodway, & Stodden, 2017). Both raters achieved a minimum of 95% inter-rater agreement for all ten FMS and seven FMS™ prior to analysis. All analysis was performed using IBM Statistical Package for Social Sciences (SPSS) for Windows version 25.0, and statistical significance was set at $p < 0.05$. Statistical analyses followed the intention-to-treat (ITT) principle, and were conducted using linear mixed models. Linear mixed models with time points (level 1) nested in persons (level 2), which have the advantage of being robust to the biases of missing data (Mallinckrodt, Watkin, Molenberghs, & Carroll, 2004), sought to determine whether there was a significant difference in mean change from baseline to post-test within and between groups in both primary and secondary outcome measures. Data were screened for outliers and implausible data. Missing data was explained by absences, school events and injuries. Fixed effects in the model included treatment group (intervention or control), time (pre- and post-intervention) and the group-by-time interaction (i.e., significant differences between groups over time). All analyses were adjusted for participants' gender, age, grade and BMI score.

6.4 Results

6.4.1 Fundamental Movement Skills

Results from the linear mixed models (Table 6.1) found a statistically significant treatment-time interaction effect, specifically with the intervention group showing greater development in the locomotor (p = .003) and overall gross motor competence (p = .002) domains. Furthermore results showed that the intervention group significantly improved in their locomotor (p = .001), object-control (p = .002), and overall gross motor competence (p = .001), from pre- to post-intervention, albeit the control group also significantly improved in locomotor (p = .001) and overall gross motor competence (p = .001).

A statistically significant increase in the intervention group from pre- to post-test across was found across all four locomotor skills assessed (Table 6.2); namely the run (p = .002), vertical jump (p = .001), horizontal jump (p = .001) and skip (p = .006). A statistically significant increase was also found in the control group in the vertical jump (p = .001) and horizontal jump (p = .004) from pre- to post-test. In terms of object control skills, both the intervention and control groups showed a statistically significant increase in the kick (p = .001), and a statistically significant decrease in the throw (p = .001) from pre- to post-test. No significant changes in perceived motor competence for FMS within or between groups was found over time (Table 6.1).

Table 6.1: Changes in mean (SD) of primary and secondary outcomes and group differences from pre- to post-test.

	Baseline Mean (SD)	Post-test Mean (SD)	*p*-value[a]	Baseline Mean (SD)	Post-test Mean (SD)	*p*-value[a]	Adjusted Difference in Change (95% CI)[b]	*p*-value[c]	ICC[d]
Primary Outcomes	**Intervention**			**Control**					
Locomotor [34]	27.55 (3.33)	31.23 (2.51)	*.001**	27.28 (3.33)	29.43 (3.11)	*.001**	1.03 (0.3 to 1.7)	*.003**	.12
Object Control [40]	32.53 (4.40)	33.53 (4.24)	*.002**	33.17 (3.98)	33.27 (3.89)	.842	0.56 (-0.3 to 1.4)	.285	.45
Overall FMS [84]	69.23 (5.98)	74.22 (5.36)	*.001**	69.95 (5.23)	71.81 (5.99)	*.005**	1.55 (0.3 to 2.9)	*.002**	.27
Functional Movement [21]	13.84 (1.69)	14.27 (1.62)	*.001**	13.81 (1.79)	13.85 (1.73)	.858	0.11 (-0.3 to 0.5)	.089	.48
Secondary Outcomes	**Intervention**			**Control**					
Perceived FMS [100]	83.06 (14.28)	83.97 (14.01)	.290	83.75 (11.07)	85.58 (16.38)	.595	-1.36 (-5.1 to 2.4)	.211	.51
Perceived Functional Movement [70]	47.72 (11.45)	48.53 (12.50)	.227	48.91 (10.73)	50.83 (13.01)	.432	-1.74 (-5.1 to 1.7)	.440	.57

a. Within-group change over time.

b. Adjusted mean difference and 95% CI between FLAME intervention and control group; adjusted for gender, grade, age and BMI.

c. Treatment-time interaction from mixed model that included baseline and post-test data.

d. ICC for gender, grade, age and BMI.

[*CI* = confidence interval; *FMS* = fundamental movement skills; *ICC* = intraclass correlation coefficient; * = $p \leq 0.01$; *SD* = standard deviation; *[ ]* = maximum possible score]

Table 6.2: Changes in mean (SD) score from pre- to post-test in Fundamental Movement Skills (FMS).

		Intervention			Control		
FMS	Maximum Score	Pre Mean (SD)	Post Mean (SD)	*p*-value	Pre Mean (SD)	Post Mean (SD)	*p*-value
Run	8	7.81 (0.52)	7.94 (0.31)	*.002**	7.82 (0.68)	7.88 (0.49)	.454
Vertical Jump	12	9.21 (1.81)	11.13 (1.25)	*.001**	8.98 (1.87)	10.25 (1.53)	*.001**
Horizontal Jump	8	5.32 (1.59)	6.71 (1.41)	*.001**	5.17 (1.63)	5.85 (1.58)	*.004**
Skip	6	5.18 (1.11)	5.41 (1.02)	*.006**	5.32 (1.14)	5.45 (1.08)	.357
Kick	8	5.54 (2.15)	7.18 (1.35)	*.001**	5.52 (1.83)	7.44 (1.03)	*.001**
Dribble	8	6.61 (1.42)	6.61 (1.51)	1.0	6.62 (1.64)	6.16 (1.59)	.090
Catch	6	5.45 (0.87)	5.30 (0.99)	.067	5.41 (0.97)	5.23 (0.94)	.207
Strike	10	8.46 (1.40)	8.59 (1.38)	.270	8.87 (1.31)	8.53 (1.30)	.096
Throw	8	6.52 (1.96)	5.90 (1.93)	*.001**	6.67 (1.80)	5.74 (2.04)	*.001**
Balance	10	9.26 (1.16)	9.40 (1.18)	.205	9.48 (0.81)	9.20 (1.59)	.174

[*SD* = standard deviation; * = $p \leq 0.01$; *FMS* = fundamental movement skills]

6.4.2 Functional Movement Screen

Based on the results from the linear mixed models (Table 6.1), a statistically significant treatment-time interaction effect was not found between groups (p = .981). However, results found that the intervention group significantly improved in their overall functional movement score (p = .001) from pre- (M = 13.84, SD = 1.69) to post-test (M = 14.27, SD = 1.62), while the control group showed no significant improvements over time.

There was a statistically significant increase in the hurdle step (p = .001), shoulder mobility (p = .001) and the trunk stability push-up (p = .001) in the intervention group from pre- to post-test (Table 6.3). There was, however, a statistically significant decrease in the rotary stability (p = .001) for the intervention group. A statistically significant increase was also found in the control group in the hurdle step (p = .001) over time, however, a statistically significant decrease was found in both the active straight leg raise (p = .001) and the rotary stability (p = .001). No significant changes in perceived functional competence within or between groups was found over time, as indicated in Table 6.1.

Table 6.3: Changes in mean (SD) score from pre- to post-test in the Functional Movement Screen (FMS™).

		Intervention			Control		
FMS™	Maximum Score	Pre Mean (SD)	Post Mean (SD)	*p*-value	Pre Mean (SD)	Post Mean (SD)	*p*-value
Active Straight Leg Raise	3	2.28 (0.64)	2.21 (0.68)	.055	2.43 (0.65)	2.00 (0.75)	*.001**
Deep Squat	3	1.62 (0.83)	1.51 (0.62)	.084	1.73 (0.83)	1.76 (0.70)	.718
Hurdle Step	3	2.12 (0.33)	2.58 (0.51)	*.001**	2.07 (0.25)	2.56 (0.50)	*.001**
In-Line Lunge	3	2.05 (0.30)	2.03 (0.17)	.416	1.98 (0.29)	2.00 (0.19)	.659
Rotary Stability	3	1.94 (0.26)	1.81 (0.39)	*.001**	1.98 (0.13)	1.68 (0.47)	*.001**
Shoulder Mobility	3	2.55 (0.65)	2.71 (0.53)	*.001**	2.49 (0.72)	2.56 (0.59)	.321
Trunk Stability Push Up	3	1.23 (0.54)	1.40 (0.70)	*.001**	1.19 (0.58)	1.33 (0.66)	.118

[*SD* = standard deviation; * = $p \leq 0.01$; *FMS*™ = Functional Movement Screen]

6.5 Discussion

This novel school-study aimed to evaluate the effectiveness of the Project FLAME intervention in terms of improving adolescent FMS and functional movement, via a non-RCT research design. The promising results of the current study indicate that a multi-component, school-based intervention can help improve motor competence among adolescents. The multi-component intervention resulted in significant treatment-time interactions for locomotor and overall FMS competence, in favour of the intervention group. Results from the Project FLAME intervention add to the body of evidence for the effectiveness of multi-component, school-based interventions (Cohen et al., 2015; McGrane, Belton, et al., 2018; Metcalf, Henley, & Wilkin, 2012).

The significant positive improvements observed in the intervention group for Project FLAME, as compared to the control group in this study may be attributed to the quality and interaction of the various components of this intervention. The four major components, including the i) specialist PE teacher component, ii) kinaesthetic classroom component, iii) student component and iv) digital literacy component, all targeted motor competence development in a holistic manner. Aligning with recommendations from previous research and reviews (Cohen et al., 2015; Kalaja, Jaakkola, Liukkonen, & Digelidis, 2012; Lander, Eather, Morgan, Salmon, & Barnett, 2017; Morgan et al., 2013; Wulf, 2013), the Project FLAME intervention included professional development practical workshops for specialist PE teachers encouraging the use of external movement-based cues and a mastery motivational climate in PE, providing developmentally appropriate activities for students, while the whole-school approach was facilitated by non-specialist PE teachers through classroom movement breaks. It is through quality targeted instruction and feedback from qualified individuals, and through practice opportunities, that children develop and improve movement skills and patterns (Bolger et al., 2019; Cohen et al., 2015; Goodway et al., 2020; Lander, Morgan, Salmon, Logan, & Barnett, 2017). Sufficient practice opportunities are necessary to master skills, and to provide students with continuing attempts for more challenging, or developmentally appropriate tasks and activities (Barnett et al., 2016; Cattuzzo et al., 2016; Chan, Ha, & Ng, 2016; Lander, Morgan, et al., 2017; Lester et al., 2017; Morgan et al., 2013; O'Brien et al., 2016a; O'Brien, Belton, & Issartel, 2016b; Robinson et al., 2015).

Improvements in FMS competence were observed in both the intervention and control groups at post-test, however, the observed improvements were significantly greater in the Project FLAME intervention group, specifically with the intervention group showing greater development in the locomotor and overall gross motor competence domains. A statistically significant increase in the intervention group was found across all four locomotor skills assessed; namely the run, vertical jump, horizontal jump and skip. Kalaja et al. (2012) highlight that locomotor skills require certain levels of explosiveness and strength to be executed properly, and it appears that by placing a particular focus on identified components of each skill through Project FLAME, students were able to refine and develop competence within these key locomotor skills. Clark (2007) argues the importance of teaching FMS right through the continuum of primary and second level schooling. A central focus must be placed on motor development within PE curricula because if these skills are not taught, then they will not develop to the expected level of competence (Clark, 2007; McGrane, Belton, et al., 2018).

The increase observed in FMS across both intervention and control groups, however, may be explained in part by the maturation process, and the natural development that occurs during childhood and adolescence (Cohen et al., 2015; Malina, Bouchard, & Bar-Or, 2004). Movement acquisition is a developmental process, over time, involving a large degree of variability in movement patterns (Lloyd et al., 2015; Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, 2012). With quality learning opportunities, individuals progress through stages from rudimentary to more advanced movement skill patterns with improved performance and consistency (Cohen et al., 2015). These FMS improvements for both control and intervention groups from the current study may be attributed to each participant having a qualified specialist PE teacher for instruction, in comparison to primary school settings in Ireland, where students do not have instructional periods with a specialist PE teacher (McGrane, Belton, et al., 2018; Morgan et al., 2013).

Although a significant treatment-time interaction effect was not found in the object control subset, significant within-group improvements were identified in the intervention group relative to the control group. This is promising as research indicates that greater practice, instruction and perceptual demands are required to develop object control skills (Bolger et al., 2019; Kalaja et al., 2012; Morgan et al., 2013). Chen, Hammond-Bennett, and Hypnar (2017) suggest that PE teachers need to provide more focussed learning opportunities for children to learn and practice a variety of object control skills. As such, increased PA opportunities alone through PE, for example, may not be sufficient to improve object control competence (Bolger et al., 2019). The positive significant findings highlight the potential of the multi-component intervention at improving object control competence of adolescents.

Object control research, as a whole, is lagging with adolescents, and this positive intervention finding will contribute to this literature. Furthermore, while gender is not analysed as a primary outcome variable within the current study, it is encouraging to see that mixed-gender intervention participants improved in their object control motor competence. It is recommended that future research examines gender, specifically to determine if Project FLAME offers a potential whole-school solution in helping to alleviate the existing gender-related differences in terms of object control skill acquisition, particularly among female adolescent youth (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; O'Brien et al., 2016a, 2018; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006).

Research has also shown that functional movement programmes consisting of corrective exercises that target an individual's 'weakest link' are effective (Bodden, Needham, & Chockalingam, 2015; Coker, 2018; Kiesel, Plisky, & Voight, 2007). For example, Coker (2018) found that replacing the traditional dynamic warm-up in PE, with a novel integrated approach that emphasises functional movement in preparation for activity in PE seems to be a pragmatic way to address movement dysfunctions in young adolescents. Essentially, Coker's (2018) findings suggested that a warm-up targeting typical physical development challenges among middle school-aged youth (such as ankle mobility, pelvic stability, and inactive and/or weak gluteal muscles), when implemented over the course of just 6 weeks, had the potential to significantly reduce functional deficiencies when compared with a traditional dynamic warm-up (Coker, 2018). Results of the current study yielded similar results to Coker (2018), with significant functional movement improvements found in the intervention group over time. Specifically, there were statistically significant increases in the hurdle step, shoulder mobility and the trunk stability push-up in the intervention group. Following the identification of poor movement patterns from Irish adolescent research (Lester et al., 2017; O'Brien et al., 2018), Project FLAME targeted correcting these movements through simple prescriptive exercises (Cook, 2010; Cook, Burton, & Fields, 2012). Corrective exercises have been developed globally to retrain measureable dysfunctional movement patterns, establish symmetrical movement, and improve balance posture (Cook, 2010; Cook et al., 2012). As is the case with this research, consistent evidence demonstrates that individuals who do not have adequate functional movement scores can improve and develop their dysfunctional movement patterns, through corrective exercise programmes (Cook et al., 2006; Dinc, Kilinc, Bulat, Erten, & Bayraktar, 2017; Letafatkar et al., 2014). The absence of a statistically significant treatment-time interaction effect in this study may be attributed in part to the existing scoring system of the FMS™, specifically the sensitivity of the FMS™ for identifying changes in whole-body function (Butler, Plisky, & Kiesel, 2012). Recent studies of the FMS™, for example, suggest that the use of a single FMS™ composite score may be flawed, given that each individual test is relatively independent in its own unique construct (Li, Wang, Chen, & Dai, 2015; Wright et al., 2016).

No significant changes in perceived motor competence within or between groups were observed over time in the current study. That said, adolescents in general from this study had high levels of perceived motor competence. This finding is interesting, as overestimation positively relates to motivation for PE, as well as engagement in PA and sports, especially among adolescents with low actual motor competence (De Meester et al., 2016). De Meester et al. (2016) found that Flemish adolescents with relatively high levels of perceived motor competence and with low actual motor competence were more physically active, when compared to adolescents with accurately perceived motor competence and low actual motor competence levels. Further research has determined that among the adolescent population globally, actual and perceived motor competence are only moderately correlated (De Meester et al., 2016; McGrane, Powell, et al., 2018). Conversely, research has also found that children who perceive their motor competence more accurately (compared to less) show more future engagement within PA (De Meester et al., 2016; Utesch et al., 2018). Developing the capability, therefore, to accurately estimate motor competence is suggested to provide more realistic expectations about an individual's competence, and should help to trigger an individual's motivation to improve skills in order to be more successful (De Meester et al., 2016; Harter, 1982). Research suggests that adolescents need to be educated, through the medium of PE, for example, to improve the ability to correctly assess their own and others' motor competence (De Meester et al., 2016). Attempts at mastery engagement, through programmes such as Project FLAME are essential for building adolescents perception of their competence (Chan et al., 2016). If students have successful attempts within motor competence tasks, they are more likely to enjoy the tasks, feel competent, and become highly motivated participants (Harter, 1978). Finally, researchers must be cognisant that an individual's physical and psychological development is a complex and multifaceted process, that synergistically evolves across time (Robinson et al., 2015).

There is empirical research informed support for school-based interventions, such as Project FLAME, to continue to address the identified lack of motor competence in children and adolescents, particularly when the evidence consistently reports that there is a strong rationale for school-based programmes aimed at increasing FMS competence (Kalaja et al., 2012; Lubans et al., 2012; McGrane, Belton, et al., 2018; Naul et al., 2018; van Beurden et al., 2003), and more recently functional movement (Coker, 2018). Specifically, as highlighted in the current study, the PE setting is a vital medium for providing developmental opportunities, and the quality of instruction is one of the most influential factors in children's development (Cohen et al., 2015; Goodway et al., 2020). Research suggests that it takes time, practice, and quality feedback from qualified personnel to increase the rate of skill development (Cohen et al., 2015). By definition, however, schools, students, and the environment differ (McGrane, Belton, et al., 2018). The lead researchers were acutely aware of these potential school, student and environmental differences, and made a conscious decision, as part of the non-RCT phase of the study, to deliver the intervention in both middle and low socioeconomic settings. The only way to adequately adjust for these inherent differences is to offer an intervention in a naturalistic setting that targets multiple variables, as is the case with Project FLAME, so that the interaction between all components allows the emergence of a new and unique behaviour (Kalaja et al., 2012; Martin, Rudisill, & Hastie, 2009; McGrane, Belton, et al., 2018)**.** The positive findings of this study add to the literature base, and support that using the established personnel and resources in the school setting, combined with effective evidence-based strategies, including student-centred approaches, is a practical method of improving motor competence in adolescent youth (Cohen et al., 2015; Kalaja et al., 2012; Morgan et al., 2013)**.**

6.5.1 Strengths, Limitations and Future Considerations

Given the uniqueness of this novel whole-school approach, the strengths of this study include the comprehensive multi-component intervention, as well as the objective and subjective measures of motor competence. Project FLAME was able to achieve a treatment-time intervention effect for adolescents' locomotor skills and overall gross motor competence, without increasing the time allocated to PE or school sport, which is important for scalability and possible future adoption in schools. A number of limitations must also be acknowledged. Firstly, the lack of any follow-up tests, particularly any long-term retention testing, is a study limitation. In addition, given that the study took place in an authentic or naturalistic setting and was delivered by school personnel, it was difficult to control the quality or indeed quantity at which each participant in the experimental group received the intervention. Furthermore, intervention components take time to become adopted and implemented in the school setting (Alfrey & O'Connor, 2020), and the lead researchers are cognisant that the 13-week intervention period was a relatively short window and should be extended in future investigations or iterations of Project FLAME. Although the research team sought to align actual and perceived measures of motor competence, perceiving oneself as competent can be somewhat independent of actual motor competence (Estevan & Barnett, 2018; Robinson et al., 2015). Essentially the clear specification in the scoring protocol used to assess actual motor competence (i.e., objective and process-oriented) is invariably different from the perceived measurements (i.e., subjective and product-oriented or outcome-based) making it difficult to truly ascertain strengths of association between actual and perceived competence (Barnett, Ridgers, Zask, & Salmon, 2015; Robinson et al., 2015).

In terms of future considerations, an in-depth analysis should be conducted on the process evaluation of Project FLAME, with a focus on fidelity, to highlight any issues that may have arisen during the implementation of this school-based intervention. This would also provide the quantitative research in this study with a more in-depth meaning. Collective intelligence (CI) methodology (Hogan, Hall, & Harney, 2017; Warfield & Cárdenes, 1993), for example, is one approach being considered by the research team for the next randomized controlled trial iteration of Project FLAME, as this methodological approach is proven to be highly acceptable and robust to elicit stakeholders' views. PE teachers engaging in Project FLAME in the future must receive ongoing professional development training to ensure that they are capable and confident at teaching movement skills and patterns throughout their lessons, while non-specialist PE teachers, should also have the necessary support available to them, to facilitate the integration of meaningful movement breaks in their classrooms. Interestingly, Coker (2018) has previously indicated that translating changes in mobility, stability, and/or motor control into FMS improvements may require an adjustment period and this is something to be aware of in terms of follow-up testing for this study. It is recommended that the implementation of the multi-component Project FLAME intervention should now be delivered for a longer duration, on a larger scale (with significant personnel and financial support) as part of a robust randomized controlled trial research design.

6.6 Conclusion

The findings of this study demonstrate the effectiveness for a multi-component, school-based intervention to promote motor competence. Results from Project FLAME's non-RCT suggest that the intervention is an effective approach to improving both FMS and functional movement among adolescents, regardless of gender, age, grade or BMI. FMS, in particular, is seen as a consistent contributor to future participation in PA and sport, and it is, therefore, imperative that their development are deemed a priority in both primary and secondary schools. The future implementation of Project FLAME as a whole-school intervention, through the concurrent involvement of specialist PE and non-specialist PE teachers (i.e., classroom teachers), using developmentally appropriate activities, may promote further motor competence development opportunities among adolescents in school and education settings.

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Chapter 7

Conclusions and Future Directions

of Project FLAME

7.1 Overview of Thesis

This PhD research study is a unique intervention trial describing the design, development, implementation and evaluation of Project FLAME, a multi-component, school-based, motor competence intervention for adolescent youth in Ireland. Project FLAME is a response to international research, including most recent Irish data, which suggests that adolescents are not performing FMS to their expected developmental capabilities (Lester et al., 2017; McGrane, Belton, Fairclough, Powell, & Issartel, 2018; O'Brien, Belton, & Issartel, 2016; O'Brien, Duncan, Farmer, & Lester, 2018), while evidence also consistently highlights deficits in functional movement patterns (Abraham, Sannasi, and Nair 2015; Anderson, Neumann, and Huxel Bliven 2015; Lester et al. 2017; O'Brien et al. 2018; Paszkewicz, McCarty, and van Lunen 2013; Portas et al. 2016).

Chapter 1 is an introduction to this thesis, providing information on the background, as well as the significance of this research study.

Chapter 2 critically reviews the literature in the areas of PL, FMS and functional movement. This chapter summarises, synthesises and discusses the literature, providing a comprehensive overview of the research in these areas to date.

Chapter 3, the first study in this thesis, gathered cross-sectional baseline data on Irish adolescent youth (N = 219; mean age: 14.45 ± 0.96 years), differentiated by gender, specifically in order to inform the development of a school-based, motor competence intervention. Overall, levels of actual mastery within FMS and functional movement were low, with significant gender differences observed.

Adolescent males scored higher in the overall gross motor skill competence domain (male mean score = 70.87 ± 7.05; female mean score = 65.53 ± 7.13), yet lower in the FMS™ (male mean score = 13.58 ± 2.59), in comparison to their female counterparts (female mean score = 14.70 ± 2.16). Considering the observed low levels of FMS and functional movement amongst the sample, this opening study suggested the need to develop a specifically designed movement-oriented intervention as a strategic step towards improving adolescent motor competence.

Chapter 4 was a particularly novel examination of the cross-sectional baseline data (N = 181; mean age: 14.42 ± 0.98 years), specifically the prevalence of movement skills and patterns, in order to generate an overall perspective of adolescent movement within the first three years (Junior Cycle) of post-primary (secondary school) education in Ireland. This study presented findings on the prevalence of mastery, differentiated by school year group, including a distinctive examination of FMS and functional movement at the behavioural component level, whereby weaknesses within performance across movements were identified. There were statistically significant age-related differences observed, with a progressive decline as age increased in both the object control ($p = 0.002$) FMS sub-domain, and the in-line lunge ($p = 0.048$) test of the FMS™. In contrast to an age-related sequential progression, as the hourglass model of motor competence would suggest (Gallahue, Ozmun, & Goodway, 2012; Goodway, Ozmun, & Gallahue, 2020), the results of this study showed emerging evidence that school year group is significantly associated with a decline in certain movement skills and patterns.

The first two studies (chapters 3 and 4) presented in this thesis refer to the cross-sectional baseline data, which investigated the gender and age-related differences in FMS and functional movement among a mixed-gender cohort of post-primary Irish adolescent youth aged 12–16 years old. Essentially, the assessment of FMS and FMS™, including the analysis of these constructs at a behavioural component level, provided a more robust evidence base for the potential development of an adolescent motor competence intervention. Understanding the trends in motor competence by gender and age provides practitioners with valuable information to implement instructional and intervention strategies, and may contribute to curriculum development, as well as policy changes (Valentini et al., 2016). According to the research questions set out in chapter 1, these studies link to the first three research questions, specifically;

Q. What are the FMS and functional movement proficiency levels of 12–16 year old Irish adolescent youth?

Q. Are there any identifiable gender and age-related differences in FMS and functional movement among post-primary Irish adolescents?

Q. Will the analysis of FMS and functional movement, at a behavioural component level, provide a more robust insight into adolescent motor competence?

Chapter 5 described the rationale and study protocol design of Project FLAME. Developing and implementing an intervention is a complex process. For this reason, it was necessary that previous literature, as well as methods and theories were reviewed prior to selecting outcome measures of motor competence in adolescent youth. It is important that previous school-based interventions were reviewed, specifically to inform the design, development and implementation of the intervention. Furthermore, it was necessary to draw on the literature, in order to target research informed motor competence strategies in adolescent youth. This chapter provides a detailed descriptive account and insight into the four major components of the Project FLAME intervention, namely the i) specialist PE teacher component, ii) kinaesthetic classroom component, iii) student component and iv) digital literacy component, all targeting motor competence development in a holistic manner. By documenting each pillar associated with Project FLAME, the reader is provided with a contextual overview of this multi-component intervention. Prior to implementation of the non-RCT however, resources and intervention components were refined, as per the feedback received from the proof-of-concept feasibility trial, as conducted with three PE teachers, who each had one class group of students (N = 78), spread across first to third year of Junior Cycle. The design, conduct and reporting of this cluster non-RCT followed the TREND guidelines for group trials (Des Jarlais, Lyles, & Crepaz, 2004). Subsequently, Project FLAME, a 13-week multi-component, motor competence intervention for post-primary schools was implemented, underpinned by the developmental model of motor competence (Robinson et al., 2015; Stodden et al., 2008). The reported study protocol design offers a feasible, targeted whole-school approach, incorporating a number of novel strategies for increasing motor competence. As per the research questions in chapter 1, the fourth research question is met here, specifically;

Q. What are the essential components required for designing, developing and implementing a school-based, motor competence intervention (as guided by the literature and baseline data measurements)?

This chapter laid the foundations for the overall evaluation of Project FLAME, as described in chapter 6.

Chapter 6 assessed the effectiveness of the Project FLAME intervention in terms of improving FMS and functional movement over a 13-week period in an Irish adolescent cohort aged 12 to 16 years of age (N = 363; mean age: 14.04 ± 0.89 years old), when compared to a control condition. The study involved two mixed gender intervention schools who received the intervention, and one mixed gender control school who received their regular PE programme only for the same period. Findings suggest that the Project FLAME intervention was an effective approach to improving FMS, and functional movement among adolescents. It was particularly encouraging to observe that the intervention was successful at improving locomotor and overall FMS gross motor competence, when compared with a control group, resulting in significant treatment-time interactions. Although a specialist PE teacher may assist in achieving improvements in motor competence, the results of this study also highlight that the Project FLAME intervention is effective in achieving significantly greater improvements in motor competence than the PE curriculum alone. Results from the Project FLAME intervention add to the body of evidence for the effectiveness of multi-component, school-based interventions (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015; McGrane et al., 2018; Metcalf, Henley, & Wilkin, 2012) and link to the fifth and final research question, as set out in chapter 1, specifically;

Q. Is it possible to increase levels of FMS and functional movement over time (pre- to post-test) in post-primary youth through the Project FLAME intervention?

FMS, in particular, is seen as a consistent contributor to future participation in PA and sport, and it is, therefore, imperative that the development of FMS is deemed a priority in both primary and post-primary (secondary) schools. The future implementation of Project FLAME as a whole-school intervention, through the concurrent involvement of specialist PE and non-specialist PE teachers (i.e., classroom teachers), using developmentally appropriate activities, may promote further motor competence development opportunities among adolescents in school and education settings.

7.2 Strengths of the Study

Acknowledging that this study contained various shortcomings, which will be discussed in the limitations section, there is strong evidence presented that the design, development, implementation and evaluation of the Project FLAME intervention was based on meticulous research considerations, evident throughout the PhD journey. The strengths of this study include:

- The range of assessment instruments used in this study were selected to give an objective measurement of gross motor competence across a range of skills, including those skills particularly relevant to the Irish sporting context and PE environment (Lester et al., 2017; O'Brien et al., 2016; Woods, Tannehill, Quinlan, Moyna, & Walsh, 2010).

- The practical objective measures of FMS and FMS™, as guided by the literature (Cook, Burton, Fields, & Kiesel, 1998; Cook, Burton, & Hoogenboom, 2006a, 2006b; Department of Education Victoria, 1996; NSW Department of Education and Training, 2000; Ulrich, 1985, 2000), combined to give a comprehensive assessment of adolescent motor competence. This is the first study of its kind in Ireland to combine both FMS and functional movement assessment in an adolescent population. Following the completion of this study, the Project FLAME research team have collected FMS and functional movement data across seventeen specific movements on over 500 adolescents, aged 12 to 16 years of age (across four years of research).

- The analysis of FMS and functional movement at a behavioural component level provided a more robust insight into the typical identifiable limitations in movement in the adolescent population, while strengthening the evidence base for the potential development of a specifically tailored motor competence intervention.

- A reliable, consistent and scientifically rigorous protocol was used during all stages of data collection, guided by previously successful FMS and functional movement methodologies worldwide (Hardy, King, Espinel, Cosgrove, & Bauman, 2010; Hume et al., 2008; Lander, Morgan, Salmon, Logan, & Barnett, 2017; Lester et al., 2017; Logan, Barnett, Goodway, & Stodden, 2017; Mitchell et al., 2013; O'Brien et al., 2016, 2018; Okely & Booth, 2004).

- The use of specific assessment instruments, characterised by an alignment between objective (i.e., actual) and subjective (i.e., perceived) measures helped the research team to further determine aspects relating to adolescent motor competence.

- As part of the baseline study, a tool to assess perceived functional movement confidence was developed (O'Brien et al., 2018). Reliability and face validity was also established for this measurement (O'Brien et al., 2018), using the physical self-confidence scale (McGrane, Belton, Powell, Woods, & Issartel, 2016) as a comparative scale for use with adolescents.

- In terms of the research rigour associated with school-based measurements, it is important to note that the lead researchers and principal investigators for this study are also qualified post-primary specialist PE teachers, as recognised by the Teaching Council of Ireland. This helped ensure a strong practitioner focus throughout the research process.

- The proof-of-concept intervention feasibility trial, as described in chapter 5, preceded and subsequently informed the larger non-RCT phase of the study. This qualitative aspect of the research, specifically the information and feedback obtained from the focus group conducted with three PE teachers, helped refine the resources ahead of the Project FLAME intervention roll out. A mixed-method approach within intervention research "*is ideal for understanding the context in which evidence-based interventions are implemented, and is the key to understanding intervention results and the success or failure of implementation efforts*" (Zhang, 2014, p.32).

- The design, conduct and reporting of this cluster non-RCT has followed the TREND guidelines for group trials (Des Jarlais et al., 2004). These guidelines emphasise the reporting of theories used and descriptions of intervention and comparison conditions, research design, and methods of adjusting for possible biases in evaluation studies that use non-randomized designs (Des Jarlais et al., 2004).

- The engagement of key stakeholders, in addition to the specialist PE teachers' within the school, namely the involvement of the principal/deputy principal and the non-specialist PE teachers (i.e., classroom teachers), facilitated the delivery of this intervention and promoted motor competence as active role models for youth (Belton, O'Brien, Meegan, Woods, & Issartel, 2014). This shift in cultural focus is similar to other whole-school approaches targeting numeracy and literacy, whereby the sole responsibility no longer resides with the Mathematics and English teacher, respectively (Department of Education and Skills 2011).

- The lead researchers were acutely aware of the potential school, student and environmental differences between settings, and made a conscious decision, as part of the non-RCT phase of the study, to deliver the intervention in both a DEIS setting (i.e., as classified by the Government of Ireland), students of which are at greatest risk of educational disadvantage (Department of Education and Skills 2017), and a non-DEIS setting.

- Crucially, the strategies formulated in Project FLAME are replicable, relatively transferable to scale, and may provide a valuable school framework for understanding adolescent motor competence in practice.

- Project FLAME was able to achieve an intervention effect for adolescents' FMS and functional movement, without increasing the time allocated to PE or school sport, which is important for scalability and possible future adoption in schools, as well as other settings.

7.3 Limitations of the Study

Despite the numerous strengths identified in the current study, it is important for future research to also consider the limitations of the study, albeit some of which were outside the control of the researcher. The limitations of this study include:

- The cross-sectional nature of the baseline data, reported in chapters 3 and 4, is a potential limitation of this research. As the convenience sample of adolescents was limited to just two post-primary (secondary) schools (N = 219; mean age: 14.45 ± 0.96 years) from the same suburban area in one Irish city, findings cannot be generalised to other adolescents.

- Age, as investigated using the baseline data, was classified using the year of enrolment in school, and not biological age, and therefore findings cannot be generalised to other adolescent populations (Lester et al., 2017).

- Although the research team sought to align actual and perceived measures of motor competence, perceiving oneself as competent can be somewhat independent of actual motor competence (Estevan & Barnett, 2018; Robinson et al., 2015). Essentially the clear specification in the scoring protocol used to assess actual motor competence (i.e., objective and process-oriented) is invariably different from the perceived measurements (i.e., subjective and product-oriented or outcome-based) making it difficult to truly ascertain strengths of association between actual and perceived competence (Barnett, Ridgers, Zask, & Salmon, 2015; Robinson et al., 2015).

- As per the data actual movement-based data collection protocol and consistent with the literature, participants received 1 practice attempt, followed by 2 performance trials in each movement, which are then assessed. It must be acknowledged, however, that there is a possibility of a learning effect as this process occurs at two time points over a period of just fifteen weeks approximately (McGrane et al., 2018).

- In relation to the assessment instruments of gross motor competence used in this study, it must be noted that the skill of the ‘strike’, as part of the TGMD-2, was developed in the United States of America (USA) and the components required to achieve mastery in this skill are culturally relevant to the USA. Specifically, the hand-grip used in the strike technique mirrors the technique required for a baseball or softball strike but is different to the hand-grip used in hurling/camogie, one of the national games (i.e., Gaelic games) of Ireland. Therefore, while it is important that the ‘strike’ is applied in an Irish context, proficiency levels in the ‘strike’, based on the criteria of the TGMD-2, may be influenced by a participant’s exposure to hurling/camogie.

- Data collection was conducted on participants in their class groups (maximum n = 30) at the same time (with a ratio of at least one trained member of field staff to every five students), through the use of a rotational station system during a typical PE class. While this protocol was effective and time-efficient, it is possible that participants may have been distracted during the demonstration of a movement, due to the presence of others in their peer group or due to the movement of other participants, including field testers, throughout the hall. Furthermore, as participants were required to wait for their own turn to attempt each movement, participants may have forgotten the visual demonstration and may also have been influenced by the attempts of their peers to perform the movements, especially those preceding their own attempts. Therefore, concentration and attention levels as well as the ability of each participant to remain patient while waiting for their turn may also have influenced performances (Bolger et al., 2019). While testing in groups was more time efficient for testers, participants were required to concentrate and perform throughout 100 minutes approximately of testing, in contrast to 15-20 minutes if tested individually. The sustained or prolonged period of focus and concentration required is unreasonable for children and youth.

- In terms of matching criteria, although all three schools as part of the non-RCT were selected for inclusion based on geographical location and gender distribution, the use of unmatched schools in terms of sample size, however, is a limitation. Of the 363 participants who provided consent for data collection measurements, for example, 266 participants (73%) were in the intervention group, while only 97 participants (27%) were in the control group. Furthermore, a school with a DEIS classification was only included in the intervention group.

- Given that Project FLAME was implemented in an authentic or naturalistic whole-school setting and was delivered by school personnel, it was difficult to control the quality or indeed quantity at which each participant in the experimental group received the intervention. A notable limitation of the study, therefore, is the absence of intervention fidelity data collected. The kinaesthetic classroom component, for example, as facilitated by classroom teachers, was not monitored during the intervention.

- A lack of meaningful information surrounding the effectiveness of the teacher training, and broader CPD in general, is further evidence of the absence of intervention fidelity data collected.

- While a detailed intervention plan and checklist was provided to the PE teachers, in conjunction with the associated teacher resource manual, the accuracy and reliability of data relating to the FMS and functional movement implementation in practice is unknown. Simply put, it was not possible to ascertain how many practice attempts were made by each participant at performing each skill and movement throughout the intervention period (i.e., during PE lessons delivered by the qualified specialist PE teacher).

- Intervention components take time to become adopted and implemented in the school setting, and the lead researchers are cognisant that the 13-week intervention period was a relatively short window for Project FLAME.

- The lack of any follow-up tests, particularly any long-term retention testing, is a study limitation.

7.4 Recommendations and Future Directions of the Project FLAME Research

A number of recommendations for future research are proposed. These future considerations include:

7.4.1 Gender/Age-Related Differences and Maturation

- In relation to the gender-related differences of participants identified across mixed-gender (i.e., co-educational) schools in this thesis (O'Brien et al., 2018), there may also be developmental differences between students who attend all boys and all girls (i.e., single-gender) schools, in terms of PA preferences and participation levels (Bolger et al., 2019), but crucially with respect to motor development. This is a potential avenue for further research.

- Primary areas for future research should use a larger longitudinal research design to track the same group of participants over time (5 year follow-up, for example), specifically to provide more insight into how and why FMS and functional movement may regress with age (Lester et al., 2017).

- Further studies, including larger cross-sectional studies and controlled trials, are also required to extend the evidence base and determine whether FMS and functional movement change over time, or throughout maturation without intervention, or if motor competence changes in response to standardised intervention programmes (Lester et al., 2017; Stobierski, Fayson, Minthorn, Valovich McLeod, & Welch, 2015).

- Biological maturity should be assessed non-invasively by incorporating measures of body mass, standing height as well as sitting height into a regression equation to predict age from peak height velocity in order to reflect the non-linear development of adolescents (Lloyd et al., 2015; Malina, Bouchard, & Bar-Or, 2004; Mirwald, Baxter-Jones, Bailey, & Beunen, 2002; Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, 2012). The performance of FMS and functional movement with consideration of biological maturation by quantifying a range of somatic measures (i.e., a surrogate of biological maturation), offer a non-invasive and more realistic approach to determining maturity status, especially within field-based environments, and may further elucidate the importance of motor competence in maturing youth (Lloyd et al., 2015; Malina et al., 2004; Mirwald et al., 2002; Quatman-Yates et al., 2012).

7.4.2 Aligning FMS and Functional Movement

- The relationship between FMS and functional movement requires further exploration. The use of either more sensitive assessment instruments or the use of biomechanical analyses to detect more subtle changes in mechanical efficiency could even be considered in the future (Coker, 2018; Lander, Nahavandi, Mohamed, Essiet, & Barnett, 2020). Most recent research has highlighted that the use of sensors, for example, to objectively and accurately measure motor competence also has the potential to minimise the ethical constraints of video-recording youth, eliminate the need to train raters to reach adequate agreement, and reduce the time of field assessment (if live coding is required) or analysis (if later video coding of assessment is conducted) for research, clinical, sport and education purposes (Lander et al., 2020).

- Future research is also recommended to confirm the scientific link between FMS and functional movement. The establishment of convergent and divergent validity between FMS and functional movement assessments would be a critical step towards the refinement of appropriate measurement tools for holistic motor competence evaluation in adolescents, within and beyond second level school PE (see Appendix A3).

7.4.3 Actual and Perceived Motor Competence

- It is necessary to continue to align measures of actual and perceived motor competence in order to determine whether perceived motor competence is a measure that truly reflects actual motor competence (Bardid et al., 2016; Barnett et al., 2015; Liong, Ridgers, & Barnett, 2015; Robinson et al., 2015). Estevan and Barnett (2018) recommend testing the relationship between actual motor competence, perceived motor competence and also cognitive development in order to analyse how these three factors interact.

- Although reliability and face validity have been identified for the perceived functional confidence scale, future research is needed to establish criterion validity (O'Brien et al., 2018).

7.4.4 Process Evaluation and Fidelity

- An in-depth analysis should be conducted on the process evaluation of Project FLAME, with a focus on fidelity, to highlight any issues that may have arisen during the implementation of this school-based intervention. This would also provide the quantitative research in this study with a more in-depth meaning

(McGrane et al., 2018). Collective intelligence (CI) methodology (Hogan, Hall, & Harney, 2017; Warfield & Cárdenes, 1993), for example, is one approach being considered by the research team for the next RCT iteration of Project FLAME, as this methodological approach is proven to be highly acceptable and robust to elicit stakeholders' views.

- For future research, it is recommended to monitor the dosage of the PE and kinaesthetic classroom components through a research-informed intervention fidelity framework, and checklist. This will help to maximize the quality and robustness of the study design, while providing further integrity to the findings and conclusions.

- Coker (2018) has previously indicated that translating changes in functional movement (i.e., mobility, stability, and/or motor control) into FMS improvements may require an adjustment period and this is something to be aware of in terms of the duration for future follow-up testing.

- It is recommended for future research that, where possible, testing should be carried out with participants on an individual basis and with minimal external distraction to ensure the most accurate assessment of motor competence (Bolger et al., 2019).

- It is recommended that the intervention group PE teachers also complete brief, digital, post-lesson reflections or evaluations, following the completion of the PE component of the intervention each week (Standal & Moe, 2013). These may be used to track evidence of best practice, by allowing the teachers to reflect on the suitability of the intervention resources (i.e., hard-copy and digital), as well as to identify teachers who may require additional support or encouragement (McGrane et al., 2018).

- In relation to adherence (i.e., teacher compliance) to intervention strategies, the adoption and implementation of intervention components (and indeed school policies) takes time and it is therefore, more appropriate and practical that motor competence and/or PA interventions are introduced at the start of the school year (Cohen et al., 2015).

- Specialist PE teachers, engaging in Project FLAME in the future must receive CPD training to ensure that they are capable and confident at teaching movement skills and patterns throughout their lessons, while non-specialist PE teachers (i.e., classroom teachers), as active role models for youth (Belton et al., 2014), should also have the necessary support available to them, to facilitate the integration of meaningful movement breaks in their classrooms (Hills, Dengel, & Lubans, 2015). This could involve teachers coming together in professional discussion, similar to Subject Learning and Assessment Review (SLAR) meetings, which are now part of the existing Irish Junior Cycle Curriculum and Framework. These teacher meetings (face-to-face) develop a greater understanding of the standards and expectations required within a subject-related programme or piece of assessment, as well as providing teachers with the opportunity to reflect on various aspects of student learning. Although some practical workshops may be required, particularly for the specialist PE teachers, virtual meetings or webinars are also worth considering, as part of future CPD training.

7.4.5 Dissemination of Project FLAME

- Based on the positive findings of this study, it is logical, and indeed essential, that the efficacy of the Project FLAME intervention be assessed as part of a RCT research design, with a larger sample to confirm results, as the medical research council (MRC) framework suggests (Campbell et al., 2000). It is recommended, therefore, that the implementation of the multi-component Project FLAME intervention should now be delivered for a longer duration and on a larger scale (with significant personnel and financial support) as part of a definitive and robust RCT research design.

- In this current study, the lead researcher served as the external contact person with the intervention schools and was available to answer any questions as they arose. For Project FLAME to be disseminated on a wider scale, it would need sufficient personnel, as well as financial backing to provide this level of support in order to ensure that the intervention was monitored, and therefore implemented as intended (McGrane et al., 2018; Mitchell et al., 2013; Naylor et al., 2015; Tompsett, Sanders, Taylor, & Cobley, 2017).

- Consultation with local, national and even international stakeholders should certainly be considered. In time, there may be potential for wider dissemination of Project FLAME, for example, to evaluate its efficacy with other populations.

- In order to achieve an even greater improvement in adolescent motor competence, Project FLAME could be integrated within extracurricular activities in the school-setting, such as lunchtime or after-school clubs, which could lead to further development of FMS, functional movement, as well as PA, particularly for at-risk groups (i.e., females, overweight/obese, those from low socioeconomic backgrounds and the inactive) (Cohen et al., 2015; D'Agostino et al., 2018; Estevan, García-Massó, García, & Barnett, 2018; Foweather et al., 2015; Hardy et al., 2010; Lander, Morgan, et al., 2017; Lunn, Kelly, & Fitzpatrick, 2013; McGrane et al., 2018; Robinson & Goodway, 2009; Robinson, Rudisill, & Goodway, 2009; Robinson, Wadsworth, & Peoples, 2012; Veldman, Jones, & Okely, 2016).

- Targeting the home environment through "*authentic engagement with parents*" (NCCA, 2018, p.5), as well as community or school-community link strategies have been found to be successful, with good compliance and satisfaction, as demonstrated in the process evaluation measures of other interventions (Cohen et al., 2015). The delivery of Project FLAME in a community setting, for example, through ongoing collaboration with local sports partnerships is recommended for future dissemination.

- Project FLAME could also be extended to the primary school setting as childhood is the optimal time to develop FMS, for example, and the primary school years represent the 'golden years' of motor development (Gallahue & Ozmun, 2006; Lander, Hanna, et al., 2017; Lander, Morgan, et al., 2017; Lubans et al., 2012).

- The recent coronavirus (COVID-19) pandemic (Xu et al., 2020; Zhu & Chen, 2020) provided further justification and indeed magnification for the integration of the digital literacy component within Project FLAME and throughout the PE curriculum as a whole, such was the necessity for a virtual learning environment (VLE).

7.4.6 A Collaborative Approach

- The collaboration between expert academics (i.e., academics with expertise in motor development research, peer-reviewed publications, PE teacher education programmes etc.) and expert practitioners (i.e., post-primary (secondary) specialist PE teachers with significant experience of teaching the PE curriculum) (Morley, van Rossum, Richardson, & Foweather, 2019), as well as student input (i.e., participant voice), where possible, will play an important role in refining the assessment protocol used in this study. The development of an assessment protocol for use by teachers needs to consider the multi-dimensional complexities of assessing motor competence in relation to the specific context in which the assessment will be conducted (Morley et al., 2019). It is necessary to provide teachers with an assessment framework that is easy to use, provides information for subsequent teaching and learning, and is ultimately embraced by the teachers who are going to use it to assess movement competence (Morley et al., 2019).

- The procurement of a professional graphic designer would be welcomed to enhance the quality of the Project FLAME resources. Furthermore, the establishment of multi-disciplinary collaborative links within the university as well as the wider community, through national governing bodies of sport, for example, is recommended for future research.

7.4.7 Motor Competence within Physical Literacy and Physical Activity

- The development of motor competence, specifically FMS, is considered an essential component and a critically important correlate of PL (Mitchell & Le Masurier, 2014; Tompsett, Burkett, & McKean, 2014), and further research is warranted to position motor competence consistently in the PL dialogue.

- The link between motor competence and PA also cannot be understated. According to Stodden et al. (2008), the general consensus of the motor development literature (Clark & Metcalfe, 2002; Haywood & Getchell, 2005; Seefeldt, 1980) is that motor competence is foundational to engagement in PA. It is recommended, therefore, for future research that PA is included within the assessment protocol as an outcome variable for Project FLAME, and any improvements in motor competence are correlated with objective measurements of PA.

- Whilst important, FMS do not reflect the broad diversity of skills utilised in PA pursuits across the lifespan (Hulteen, Morgan, Barnett, Stodden, & Lubans, 2018). The term ‘foundational movement skills’, proposed by Hulteen et al. (2018), may better reflect the broad range of movement forms that increase in complexity and specificity and can be applied in a variety of settings. ‘Foundational movement skills’ includes both traditionally conceptualized ‘fundamental’ movement skills and other skills (e.g., bodyweight squat, cycling, swimming strokes) that support PA engagement across the lifespan (Hulteen et al., 2018). The holistic approach to motor development through the simultaneous integration of both FMS and functional movement within Project FLAME, adds further merit to Hulteen et al.'s (2018) conceptual model for PA. Understanding movement skills that may be performed across the lifespan are important so that skill development in youth may be related to general health and quality of life into our elderly years (Hulteen et al., 2018). To advance the application of motor development principles within the public health domain, it is important to examine the potential lifespan development of motor competence to various aspects of physical health (Hulteen et al., 2018).

7.4.8 Implications for Policy and Practice

- From September 2020, for the first time in the history of formal state examinations in Ireland, post-primary (secondary) schools in Ireland and in particular, PE teachers, will be required to record student achievements and report on PE within wellbeing in junior cycle (NCCA, 2017), as part of each individual student's Junior Cycle Profile of Achievement (JCPA) (NCCA, 2018). Robust assessment and reporting practices within schools are one way to advocate for PE as a subject. Project FLAME may provide a useful framework for both teachers and students in the development of a movement culture within schools.

- Although there is no reference to motor development or related constructs within the guidelines for wellbeing in junior cycle (NCCA, 2017), the prescribed short course PE specification for junior cycle (NCCA & Department of Education and

Skills, 2016) states that PE "*can provide all students with enjoyable and worthwhile learning opportunities where they develop the movement skills and competencies to participate and perform in a variety of physical activities competently, confidently and safely*" (NCCA & Department of Education and Skills, 2016, p.4). Furthermore, within this framework, the games strand highlights how students should learn "*to develop a range of transferable movement skills and competencies and the ways in which these can be used within and across the different games categories*" (NCCA & Department of Education and Skills, 2016, p.9). Future research, however, should consider integrating and adapting Project FLAME within the development of a school-designed short course in PE, using the NCCA template, specifically the guidelines for developing and writing a short course (NCCA, 2019). This would help establish a link motor competence and the school curriculum while extending the evidence base for Project FLAME.

- Reference to "*fundamental skills*" within the National Physical Activity Plan (NPAP) for Ireland (Healthy Ireland, 2016, p.18), as well as "*motor skills*" and FMS within the World Health Organization's (WHO) new global action plan to promote PA (World Health Organization, 2018), confines FMS to the education sector, primarily the school-based PE environment. This confinement renders the potential impact of motor competence as a determinant of PA as somewhat limited, or even non-existent, contrary to the literature presented in this thesis. Project FLAME has the potential to continue to extend the evidence base and advance the justification for motor competence within health education and indeed health policy, at both a national and global level. Those working in the field of motor development, however, need '*a seat at the table*'.

7.5 Closure – The Conclusion of this PhD Journey

The overall aim of this thesis was to design, develop, implement and evaluate the efficacy of Project FLAME: A multi-component, school-based, motor competence intervention for adolescent youth in Ireland. Project FLAME is the first of its kind in Ireland seeking to critically examine and develop adolescent motor competence, at both a fundamental and functional movement level. The reported study offers a feasible, targeted whole-school approach to increasing motor competence, and by incorporating a number of novel strategies, the findings may have important implications for the future teaching and learning of PE at post-primary level. This project also has the potential to extend the evidence-base for programmes aiming to increase movement vocabulary, overall health, wellbeing and PA participation in young people.

Acknowledging the study design strengths and limitations, the findings of the non-RCT highlight that Project FLAME is a promising approach for enabling adolescent youth to improve their motor competence. Further analysis must be conducted on the process evaluation of Project FLAME, with a focus on fidelity, to determine whether the programme can be delivered on a larger scale in post-primary schools as well as other settings. This PhD research study has successfully ensured that the project can now move to the next stage of evaluation through a definitive RCT.

The research process for designing, developing, implementing and evaluating this study has refined my thinking and practice, while writing this PhD thesis has helped clarify my thinking. This journey has been challenging, relentless, but above all else, a fruitful learning experience. Although I have now learned how to conduct research as an independent researcher, it is the collaborative approach that defines this research and one I will continue to advocate for. As a PhD candidate, working as a PE and Irish teacher in a post-primary (secondary) school, I have been in the advantageous and privileged position to see research in practice on a daily basis. Ultimately, I see it as my responsibility to continue to communicate this research, and that of others, to advance the field of PE and to support the development of adolescent youth with whom I have been entrusted to work with.

7.6 References

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Appendices

Appendix A:

Publications

A1	Published Paper – Sports 2017
A2	Published Paper – Journal of Motor Learning and Development 2018
A3	Published Paper – Women in Sport and Physical Activity Journal 2018
A4	Published Paper – International Journal of Environmental Research and Public Health 2020

sports MDPI

Article

The Age-Related Association of Movement in Irish Adolescent Youth

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Abstract: (1) Background: Research has shown that post-primary Irish youth are insufficiently active and fail to reach a level of proficiency across basic movement skills. The purpose of the current research was to gather cross-sectional baseline data on Irish adolescent youth, specifically the prevalence of movement skills and patterns, in order to generate an overall perspective of movement within the first three years (Junior Certificate level) of post-primary education; **(2) Methods:** Data were collected on adolescents (N = 181; mean age: 14.42 ± 0.98 years), attending two, mixed-gender schools. Data collection included 10 fundamental movement skills (FMS) and the seven tests within the Functional Movement Screen (FMS™). The data set was analysed using the Statistical Package for Social Sciences (SPSS) version 20.0 for Windows; **(3) Results:** Overall, levels of actual mastery within fundamental and functional movement were low. There were statistically significant age-related differences observed, with a progressive decline as age increased in both the object control ($p = 0.002$) FMS sub-domain, and the in-line lunge ($p = 0.048$) test of the FMS™; **(4) Conclusion:** In summary, we found emerging evidence that school year group is significantly associated with mastery of movement skills and patterns. Results from the current study suggest that developing a specifically tailored movement-oriented intervention would be a strategic step towards improving the low levels of adolescent fundamental and functional movement proficiency.

Keywords: age; fundamental movement skills; functional movement screen; adolescent

1. Introduction

Research has established that levels of physical activity (PA) participation decline significantly during adolescence [1,2]. The ability to perform a variety of fundamental movement skills (FMS) may serve as a protective factor against this trend however [3,4], with empirical evidence suggesting that proficiency in FMS is positively associated with PA participation [4–7]. Therefore, strategies to improve PA participation may need to consider ensuring that adolescents have competency in basic movement patterns [8–11], at both a fundamental and functional movement level [12–14].

FMS are considered the basic observable building blocks, or precursor patterns of the more specialised, complex movement skills required to successfully participate in organised and non-organised games, sports and recreational activities [15,16]. Examples exhibited during sport, exercise and PA include running, hopping, skipping (locomotor), throwing, catching, kicking (object control),

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Human Kinetics
ORIGINAL RESEARCH

Do Irish Adolescents Have Adequate Functional Movement Skill and Confidence?

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Recent research has shown that post-primary Irish youth are insufficiently active and fail to reach a level of proficiency across basic fundamental movement skills. The purpose of the current research was to gather cross-sectional data on adolescent youth, differentiated by gender, specifically to inform the development of a targeted movement-oriented intervention. Data were collected on adolescents ($N = 219$; mean age : 14.45 ± 0.96 years), within two, mixed-gender schools. Data collection included actual and perceived movement measurements comprised of fundamental movement skills, the functional movement screen, perceived movement confidence, and perceived functional confidence. Overall, levels of actual mastery within fundamental and functional movement were low, with significant gender differences observed. Adolescent males scored higher in the overall fundamental movement skill domain (male mean score = 70.87 ± 7.05; female mean score = 65.53 ± 7.13), yet lower within the functional movement screen (male mean score = 13.58 ± 2.59), in comparison to their female counterparts (female mean score = 14.70 ± 2.16). There were high levels of perceived confidence reported within fundamental and functional movement scales. Future intervention strategies should combat the low levels of actual movement skill proficiency, while identifying the reasons for higher perceived movement confidence within adolescents.

Keywords: functional movement screen, fundamental movement skill, motor development

Physical literacy has been previously defined as having the motivation, confidence, physical competence, understanding, knowledge, skills, and attitudes

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Human Kinetics
ARTICLE

Enhancing the Evidence Base for Irish Female Youth Participation in Physical Activity—The Development of the Gaelic4Girls Program

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The purpose of the current research was to gather baseline data on female youth to inform the development of a targeted physical activity (PA) and sports-based intervention, specifically identified as "Gaelic4Girls". Cross-sectional data on PA levels, psychological correlates of PA, anthropometric characteristics, and the fundamental movement skill (FMS) proficiency of female youth ($n = 331$; M age 10.92±1.22) were collected. A subsample ($n = 37$) participated in focus group (FG) interviews exploring perceptions of health/sport, and identifying barriers/motivators to participation. PA levels were assessed using self-report (PA Questionnaire for Older Children) and classified as low, moderate, and high active. One- and two-way ANOVAs (post hoc Tukey honest significant difference [HSD]) were used to analyze the data. The FGs were transcribed verbatim, coded, and thematically analyzed. Findings indicated that the majority of youth (71.8%) were not meeting the minimum daily PA recommendations for health, and that 98.1% did not achieve the FMS proficiency expected for their age. Low, moderately, and highly active participants differ significantly in terms of overall FMS ($p = .03$), and locomotor control scores ($p = .03$). FG findings report fun and friendship as key PA motivators, too much competitiveness as barriers, and positive outside encouragement from family/friends/coaches as facilitators encouraging PA engagement. Findings highlight the need for targeting low levels of PA, FMS proficiency in female youth sport interventions, through addressing self-efficacy levels, inclusive of fun, and socially-stimulating PA environments.

Keywords*:* fundamental movement skill, physical activity motivators and barriers, psychosocial physical activity correlates, sport participation

It is well established that regular participation in physical activity (PA) is imperative for good health (Eime, Young, Harvey, Charity, & Payne, 2013). While PA of any type will deliver an array of physical, psychological, and social health benefits (Biddle & Asare, 2011), research continues to show that lack of PA participation among children and adolescents is a global concern (Guthold, Cowan, Autenrieth, Kann, & Riley, 2010). According to previous data obtained from 105 countries, 80% of children aged 13 to 15 years fail to meet the recommended public health guidelines of 60 min of moderate-to-vigorous physical activity (MVPA) per day (Hallal et al., 2012). In an Irish context, the most recent 2016 Report Card on PA (a national document, containing all data on indicators related to children's PA levels from Northern and Southern Ireland) awarded children and adolescents an overall grade of "D" for low PA participation (Harrington, 2016).

Further to these low levels of PA participation, a consistent gender-based disparity in PA among adolescents exists, whereby females are significantly less active than males (Marques, Ekelund, & Sardinha, 2016; Telford, Telford, Olive, Cochrane, & Davey, 2016). A notable decrease in PA participation during adolescence has been observed, with a higher risk of decline among girls (Bradley et al., 2011; Woods, Tannehill, Quinlan, Moyna, & Walsh, 2010). On a national level, the Growing Up in Ireland National Longitudinal Study (2010; Layte & McCrory, 2011) found a significant gender differential visible among 9-year-olds,

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Article

Investigating the Age-Related Association between Perceived Motor Competence and Actual Motor Competence in Adolescence

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Abstract: Irish adolescents have been found to possess high perceptions of motor competence. However, there is an evidential value to investigating the strength of the relationship between adolescent perceptions of motor competence and their low levels of actual motor competence. The purpose of this research was to gather data on the fundamental, functional, and perceived motor competence in adolescents, differentiated by year group, to discern if participants could assess their perceptions of ability. Data were collected on adolescents (N = 373; mean age: 14.38 ± 0.87 years; 47.7% female) across six second-level schools in Ireland, including measurements of fundamental movement skills, functional movement, and perceived motor competence. Poor levels of fundamental and functional movement were observed, with significant differences between year groups detected. Participants in 1st year scored the highest in overall fundamental movement skills; however, for overall functional movement, 3rd-year participants scored highest. High levels of perceived motor competence were reported across the entire sample. These scores did not align with actual motor competence, nor did any alignment between these measurements improve with aging, countering theorized age-related associations. Future research should target low levels of actual motor competence while emphasizing the cognitive aspects of movement to ensure greater accuracy between actual and perceived motor competence.

Keywords: functional movement; fundamental movement skills; motor competence; cognition; motor skills

1. Introduction

Global adolescent physical activity (PA) levels remain at disconcertingly low levels, with few signs of future improvements [1]. As low PA levels are associated with a higher degree of obesity and an increased risk of non-communicable diseases, increasing PA levels must become a vital part of future initiatives to improve the health status of future generations [2]. Irish PA participation levels for children and youth remain perilously low, with only 13% meeting current recommendations of 60 min of PA per day [3]. Childhood and adolescent PA patterns typically subsist throughout the lifespan, clearly underlining the importance of establishing an active lifestyle as early as possible [4].

Appendix B:

School and Parent/Guardian Correspondence

B1	Letter to School Management
B2	Plain Language Statements and Informed Consent Forms
B3	Foirm Toilithe

[redacted]

2nd October 2017

2 Lucan Place,
Western Road,
University College Cork,
Cork.

Dear [redacted],

I am a [redacted] research student in the School of Education, University College Cork, specifically within the Sports Studies and Physical Education programme with Dr. Wesley O'Brien and Dr. Fiona Chambers as supervisors.

The purpose of my research, entitled *Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency*, is to critically examine the psychomotor competencies of movement (i.e. fundamental and functional) within Irish adolescent youth in order to generate an overall perspective of childhood movement at post-primary, Junior Cycle level. There is growing knowledge in the wider community of the importance of these basic movement skills and patterns to counteract the prevalence of sedentary behaviour, screen time and obesity by ensuring our children and adolescents have the necessary movement base to enable them participate in lifelong physical activity.

This year the research team is hoping to collect data on first, second and third year students across three mixed-gender post-primary schools in Cork, following which students will receive a 13-week movement-oriented intervention for a duration of 10-15 minutes during their timetabled PE class as administered by each group's respective PE teacher. At this point I would like to formally invite your school to partake in this phase of the project. The data referred to above includes the testing of ten fundamental movement skills (kick, throw, jump, run etc.) and seven functional movement patterns (flexibility, mobility, stability) in a controlled environment in your school's sports hall. It is hoped that each participating school will provide two classes from each year group (i.e. first, second and third). Data will then be collected during a two-day school visit by the research team, at two separate time points during the school year. Crucially, the full range of tests will be carried out on a full class group (i.e., 30 students) within three consecutive class periods so disruption to classes will be minimal.

All equipment for this testing will be brought to the school by the research team, and as the sports hall will be required, we are asking that the school hall be made available for two full days, on two separate occasions throughout the school year. In return, the PE teachers involved in this study will receive two in-service training workshops (including hard-copy and digital resource packs) to assist with the implementation of the intervention, while the PE Department in the school will be provided with detailed descriptive results of how their students performed which will be an invaluable asset in terms of long-term planning at both a departmental and school level. However, please note that no information of individual student performances will be provided in line with ethical considerations for the project as approved by the Social Research Ethics Committee (SREC) in UCC. Furthermore, no reference to your school will be made on any future publications arising from the data collected, again in line with ethical considerations.

I would be grateful if you could inform the PE teachers in your school of this project and consider your school's involvement. It would mean a lot to the project to have [redacted] involved. Please find some additional information, including dates and a timeline for the intervention, attached on the following page. I appreciate that there is a lot of information in this letter so with that in mind, I would be more than willing to call into your school in the coming days, at your convenience, to meet with you and/or your staff to discuss any details that may be outstanding. Alternatively, please do not hesitate to contact me via phone or email.

Is mise le meas,

Diarmuid Lester, B.Ed.
Principal Investigator.

Ph.D. Candidate
Sports Studies and Physical Education
School of Education
University College Cork
Tel: [redacted]
Email: [redacted]

Project FLAME 2017-18

Title: Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency

Principal Investigators: Dr. Wesley O'Brien and Mr. Diarmuid Lester

University Department: Sports Studies and Physical Education

Key Dates and Intervention Timeline

[redacted]

Dates for Testing 1 (Pre): Dates for Testing 2 (Post):	Monday **23rd** & Tuesday **24th** October 2017 Monday **12th** & Tuesday **13th** March 2018
Teacher Workshop 1: Teacher Workshop 2:	Week of Monday 20th November 2017 (Date and Time TBC) Week of Monday 8th January 2018 (Date and Time TBC)
Intervention Overview: Intervention start date:	**13-week intervention** (4 weeks before Christmas and 9 weeks after Christmas) Week of Monday 27th November 2017

Plain Language Statement

Title: Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency

Principal Investigators: Dr. Wesley O'Brien and Mr. Diarmuid Lester

University Department: Sports Studies and Physical Education

Involvement in the Research Study

- My school is involved in a movement study entitled *Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency*.
- The research project will be carried out by the Sports Studies and Physical Education programme, School of Education, University College Cork.
- Dr. Wesley O'Brien, Dr. Fiona Chambers and Mr. Diarmuid Lester will be carrying out the study in my school.
- My parents/guardians have spoken to me about being part of the research study.

This is what will be involved in the study:

- I may be measured to see:
  *how I move; run, horizontal jump, strike, stationary dribble, catch, kick, overhand throw, skip, vertical jump
  *how flexible I am; straight leg raise.
  *how well I can keep my balance; static balance, squat and lunge.
  how tall I am and how much I weigh.
- I may be asked to complete a physical activity and/or movement based questionnaire. This questionnaire will be filled out in class with the help of my teacher and Mr. Diarmuid Lester.
- I may be asked to wear a small device (accelerometer) around my waist to measure how much I move in a specific length of time (7 days).
- I understand that I can stop being part of this study any time I want to. I will let my parent/guardian, teacher or Mr. Diarmuid Lester know and I will not have to take part.
- I understand that all the information I give will be completely confidential (kept secret) - no one will get to look at it except Dr. Wesley O'Brien, Dr. Fiona Chambers and Mr. Diarmuid Lester.
- If I have any questions about the study that I do not understand I will ask my parents/guardians, my teacher or Mr. Diarmuid Lester.

Primary Investigators and Contact Details:

Title	First Name	Surname	Phone	Institution	Email
Dr.	Wesley	O'Brien	[redacted]	Sports Studies & Physical Education, University College Cork.	[redacted]
Mr.	Diarmuid	Lester		Sports Studies & Physical Education, University College Cork.	[redacted]

**This will be recorded using a video camera in my PE class.*

Plain Language Statement

Title: Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency

Principal Investigators: Dr. Wesley O'Brien and Mr. Diarmuid Lester

University Department: Sports Studies and Physical Education

Involvement in the Research Study

- My school is involved in a movement study entitled *Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency*.
- The research project will be carried out by the Sports Studies and Physical Education programme, School of Education, University College Cork.
- Dr. Wesley O'Brien, Dr. Fiona Chambers and Mr. Diarmuid Lester will be carrying out the study in my school.

Principal Investigators and Contact Details:

Title	First Name	Surname	Phone	Institution	Email
Dr.	Wesley	O'Brien	[redacted]	Sports Studies & Physical Education, University College Cork.	[redacted]
Mr.	Diarmuid	Lester		Sports Studies & Physical Education, University College Cork.	[redacted]

If you have any queries regarding the conduct of this project you can contact:
Office of the Vice President for Research & Innovation, 4th Floor Block E, Food Science Building, UCC.
Tel: 021-4903501 Email: uccresearch@ucc.ie

Informed Consent Form

18th October 2017

Dear Parent/Guardian,

Please find overleaf an informed consent form for your child's participation in a movement study entitled ***Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency***. This study is being carried out by University College Cork in your child's school. The study aims to gather information on the movement vocabulary and physical activity levels of students in the school and develop a plan to help improve these levels, and then to assess whether or not activity levels have been improved.

In order for your child to participate in this study, please read the attached form. If you do not wish your child to be involved then you need to take no further action. If you DO wish your child to participate in the study then I kindly request that both you and your child sign and return Option 2 at the bottom of the form.

Thank you for your time.

Yours sincerely,

____

Wesley O'Brien Ph.D.
Principal Investigator

Informed Consent Form

Project Title: Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency

Investigators: Dr. Wesley O'Brien, Dr. Fiona Chambers and Mr. Diarmuid Lester.

Introduction to the study:
The ability to move with fundamental and functional competence has been shown to be extremely beneficial to youth in enabling them to move well and move often and therefore a key determining factor in physical activity participation. In order to develop effective physical activity programmes for your (child's) age group, it is important that researchers understand the factors that influences adolescents in Ireland to become and remain active.

This is what will happen during the research project:

- Your child may be recorded using a video camera in PE class to measure how well they can:
    - run; horizontal jump; strike; stationary dribble; skip; vertical jump; static balance; catch; kick and; overhand throw.
- Your child may be recorded using a video camera in PE class to assess the following:
    - deep squat; hurdle step; in-line lunge; shoulder mobility; active straight leg raise; trunk stability push-up and; rotary stability test.
- Your child may have their height and weight measured.
- Your child may complete a physical activity and/or movement based questionnaire. This questionnaire will be filled out in class with the help of the class teacher and Mr. Diarmuid Lester.
- Your child may be asked to wear a small device (accelerometer) around their waist to measure how much they move in a specific length of time (7 days). Each parent/guardian may receive an automated text message on their mobile phone each morning from their child's school or the research team reminding their children to put on the accelerometer.

All information gathered will be treated in the strictest of confidence. To ensure this, your child's name will be removed from all data and replaced with an ID number. Only the researchers will know your child's ID number, and only the researchers will have access to the information.

Sports Studies & Physical Education

UCC

<u>Please read Option 1 and Option 2 below and complete as appropriate.</u>

<u>Option 1</u>: <u>Child to be removed from the study</u>

I have read and understood the information in this form. I have read and explained the information in the form to my child. The researchers have answered my questions and concerns, and I have a copy of this consent form. I request that my child is **<u>not</u>** included in the study. I understand that my child will not be penalised in any way for doing this.

ACTION: No further action necessary. Please file this consent form for future reference.

<u>Option 2</u>: <u>Child to be included in the study</u>

I have read and understood the information in this form. I have read and explained the information in the form to my child. The researchers have answered my questions and concerns, and I have a copy of this consent form. I understand that all students, including my child, are included in this study.

ACTION: To advise the research team of your decision please sign and return this form to your child's PE teacher.

Parent/Guardian's Signature: ____________________________________

Parent/Guardian's Name in BLOCK CAPITALS: ____________________________________

Child's Signature: ____________________________________

Child's Name in BLOCK CAPITALS: ____________________________________

Date: ________________________

Informed Consent Form

I. Research Study Title

Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency

II. Clarification of the purpose of the research

Recent research has shown that the majority of post-primary Irish youth are insufficiently active and fail to reach a level of proficiency across basic movement skills (Belton et al., 2014; Lester et al., 2017; O'Brien et al., 2013; 2016; 2018). The purpose of this research is to critically examine movement proficiency, at both a fundamental and functional level, in post-primary Irish adolescent youth (12-16 years), specifically in order to generate an overall perspective of childhood movement and motor development. There is growing knowledge in the wider community of the importance of these basic movement skills and patterns to counteract the prevalence of sedentary behaviour, screen time and obesity by ensuring our children and adolescents have the necessary movement base to enable them participate in lifelong physical activity. This project will extend the evidence-base for feasible childhood programmes, specifically aiming to increase movement vocabulary, overall health, wellbeing and physical activity participation.

III. Confirmation of particular requirements as highlighted in the Plain Language Statement

<u>Participant – please complete the following (Circle Yes or No for each question)</u>

Have you read or had read to you the Plain Language Statement	*Yes/No*
Do you understand the information provided?	*Yes/No*
Have you had an opportunity to ask questions and discuss this study?	*Yes/No*
Have you received satisfactory answers to all your questions?	*Yes/No*

Involvement in the research is completely voluntary. Participants may choose to withdraw from the study at anytime. There shall be no penalty for withdrawing before all stages of the research project have been completed**.** Confidentiality is an important issue during data collection. Participant's identity, or other personal information, will not be revealed or published. Participants will be assigned an ID number, or a pseudonym, under which all personal information will be stored in a secure file and saved in password protected file in a computer at UCC. The investigators alone will have access to the data. Confidentiality of information provided can only be protected within the limitations of the law. It is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions.

I have read and understood the information in this form. My questions and concerns have been answered by the researchers, and I have a copy of this consent form. Therefore, I consent to take part in this research project.

Participant's Signature: ____

Name in BLOCK CAPITALS: ____

Date: ______________________

Foirm Toilithe

18ú Deireadh Fómhair 2017

A Thuismitheoir/Chaomhnóir,

Gheobhaidh tú foirm toilithe lastall bainteach le rannphairtíocht do pháiste i dtionscadal corpoideachais dar teideal ***Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency***. Tá an tionscadal seo á reachtáil ag Coláiste na hOllscoile, Corcaigh, i meánscoil do pháiste. An aidhm atá leis an tionscadal seo ná eolas a bhailiú faoi ghluaiseacht ag an aois seo mar aon le leibhéil aclaíochta dhaltaí na scoile. Beidh plean á chur i bhfeidhm a chabhróidh le daltaí feabhas a chur ar na leibhéil seo agus ansan beidh measúnú á dhéanamh arís chun tionchar an phlean a thomhas.

Chun a chinntiú go mbeidh do pháiste páirteach sa staidéar seo, léigh an fhoirm atá ceangailte. Mura bhfuil fonn ort go mbeidh do pháiste páirteach sa staidéar, ní gá duit a thuilleadh a dhéanamh. Má tá fonn ort go mbeidh do pháiste páirteach sa staidéar seo, iarraim ort go síneofá agus do pháiste **Rogha 2** thall agus é a thabhairt ar ais chun na scoile.

Go raibh maith agat as ucht do chuid ama.

Is mise le meas,

Wesley O'Brien Ph.D.
Príomh-Imscrúdaitheoir

Foirm Toilithe

Teideal an Tionscadail: Project FLAME: Fundamental and Functional Literacy for Activity and Movement Efficiency

Imscrúdaitheoirí: an Dochtúir Wesley O'Brien, an Dochtúir Fiona Chambers agus an tUasal Diarmuid Lester.

Réamhrá:
Léiríonn taighde go bhfuil nasc agus tionchar idir an duine atá in ann bogadh le cumas bunúsach agus feidhmiúil agus an duine atá páirteach in aclaíocht go leanúnach. Tá sé fíor-thábhachtach mar sin go bhfuilimid ag cur pleananna aclaíochta i bhfeidhm d'aois ghrúpa do pháiste a chinnteoidh go mbeidh forbairt á dhéanamh ar na bunscileanna ag na déagóirí seo.

Is é seo an méid a tharlóidh i rith an tionscadail:

- Beidh taifead (físcheamara) á dhéanamh ar do pháiste le linn an rang corpoideachais chun measúnú a dhéanamh ar na nithe seo a leanas:
    - rith; léim; pocáil; druibleáil; scipeál; breith; cic; caith; cothromaíocht; solúbthacht; lúth agus cobhsaíocht.
- Beidh airde agus meáchan do pháiste á thomhas.
- Líonfaidh do pháiste ceistneoir bunaithe ar an méid aclaíochta atá á dhéanamh aige/aici. Líonfar an ceistneoir sa rang le cabhair ón múinteoir ranga agus an tUasal Diarmuid Lester.
- Iarrfar ar roinnt daltaí gléas beag (*'accelerometer'*) a chaitheamh timpeall na coime ar feadh tréimhse ocht lá. B'fhéidir go seolfaidh an fhoireann taighde téacs amach ar maidin chuig an tuismitheoir/caomhnóir le linn an tréimhse seo chun a chur i gcuimhne don pháiste an *accelerometer* a chaitheamh.

Beidh an t-eolas a bhaileofar go hiomlán faoi rún. Chun an méid seo a chinntiú, bainfear ainm do pháiste agus úsáidfear uimhir aitheantais ina áit. Is iad na h-imscrúdaitheoirí thuasluaite an t-aon dream go mbeidh na huimhreacha seo acu agus is iad na h-imscrúdaitheoirí an t-aon dream go mbeidh fáil acu ar an eolas freisin.

Léigh Rogha 1 agus Rogha 2 thíos agus líon isteach de réir mar is cuí.

Rogha 1: An páiste tógtha as an staidéar

Léigh mé agus thuig mé an t-eolas atá ar an bhfoirm seo. Léigh mé agus mhínigh mé an t-eolas atá ar an bhfoirm seo do mo pháiste. D'fhreagair na taighdeoirí mo cheisteanna agus tá cóip agam den fhoirm seo. Iarraim **nach** mbeidh mo pháiste páirteach sa staidéar seo. Tuigim nach mbeidh aon phionós á ghearradh ar mo pháiste mar thoradh ar an gcinneadh seo.

GNÍOMH: Ní gá a thuilleadh a dhéanamh. Coimeád an fhoirm seo le húsáid amach anseo.

Rogha 2: Páiste le bheith páirteach sa staidéar

Léigh mé agus thuig mé an t-eolas atá ar an bhfoirm seo. Léigh mé agus mhínigh mé an t-eolas atá ar an bhfoirm seo do mo pháiste. D'fhreagair na taighdeoirí mo cheisteanna agus tá cóip agam den fhoirm seo. Tuigim go bhfuil gach dalta, mo pháiste ina measc, páirteach sa staidéar seo.

GNÍOMH: Sínigh agus líon an fhoirm seo agus seol ar ais go dtí múinteoir corpoideachais do pháiste é.

Síniú Tuismitheora/Caomhnóra: ______________________________

Ainm i gCEANNLITREACHA : ______________________________

Síníú an Pháiste: ______________________________

Ainm an Pháiste i gCEANNLITREACHA: ______________________________

Dáta: ____________________

Appendix C:

Data Collection Material

C1	Fundamental Movement Skills (FMS) Performance Criteria
C2	Functional Movement Screen (FMS™) Scoring Criteria
C3	Perceived Motor Competence Questionnaires

Fundamental Movement Skills (FMS)

Performance Criteria

BALANCE [GET SKILLED: GET ACTIVE]
(1) Support leg still, foot flat on the ground.
(2) Non-support leg bent, not touching the support leg.
(3) Head stable, eyes focused forward.
(4) Trunk stable and upright.
(5) No excessive arm movements.

CATCH [TGMD]
(1) Preparation phase where hands are in front of the body and elbows are flexed.
(2) Arms extend while reaching for the ball as it arrives.
(3) Ball is caught be hands only.

DRIBBLE [TGMD-2]
(1) Contacts ball with one hand at about the belt level.
(2) Pushes ball with fingertips (not a slap).
(3) Ball contacts surface in front of or to the outside of foot on preferred side.
(4) Maintains control of ball for four consecutive bounces without having to move the feet to retrieve it.

HORIZONTAL JUMP [TGMD-2]
(1) Preparatory movement includes flexion of both knees with arms extended behind body.
(2) Arms extend forcefully forward and upward reaching full extension above the head.
(3) Take off and land on both feet simultaneously.
(4) Arms thrust downward during landing.

KICK [TGMD-2]
(1) Rapid continuous approach to the ball.
(2) An elongated stride or leap immediately prior to ball contact.
(3) Non-kicking foot placed even with or slightly in back of the ball.
(4) Kicks ball with instep of preferred foot (shoelaces) or toe.

RUN [TGMD-2]
(1) Arms move in opposition to legs, elbows bent.
(2) Brief period where both feet are off the ground.
(3) Narrow foot placement landing on heel or toe.
(4) Non-support leg bent approximately 90 degrees.

SKIP [TGMD]
(1) A rhythmical repetition of the step-hop on alternate feet.
(2) Foot of non-support leg carried near surface during the hop phase.
(3) Arms alternately moving in opposition to legs at about the waist level.

STRIKE [TGMD-2]
(1) Dominant hand grips bat above non-dominant hand.
(2) Non-preferred side of body faces the imaginary tosser with feet parallel.
(3) Hip and shoulder rotation during swing.
(4) Transfers body weight to front foot.
(5) Bat contacts ball.

THROW [TGMD-2]
(1) Wind-up is initiated with downward movement of hand/arm.
(2) Rotates hip and shoulder to a point where the non-throwing side faces the wall.
(3) Weight is transferred by stepping with the foot opposite the throwing hand.
(4) Follow-through beyond ball release diagonally across the body towards the non-preferred side.

VERTICAL JUMP [GET SKILLED: GET ACTIVE]
(1) Eyes focused forward or upward throughout the jump.
(2) Crouch with knees bent and arms behind the body.
(3) Forceful forward and upward swing of the arms.
(4) Legs straighten in air.
(5) Land on balls of feet and bend knees to absorb landing.
(6) Controlled landing with $\leq$1 step any direction.

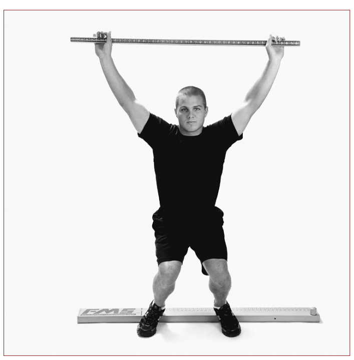
DEEP SQUAT

3

Upper torso is parallel with tibia or toward vertical | Femur below horizontal
Knees are aligned over feet | Dowel aligned over feet

2

Upper torso is parallel with tibia or toward vertical | Femur is below horizontal
Knees are aligned over feet | Dowel is aligned over feet | Heels are elevated



1

Tibia and upper torso are not parallel | Femur is not below horizontal
Knees are not aligned over feet | Lumbar flexion is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

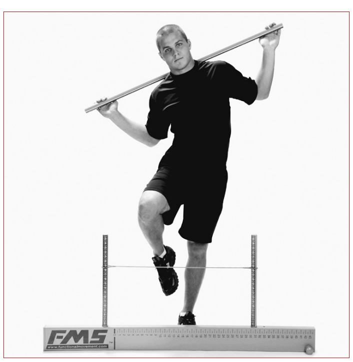
HURDLE STEP

3

Hips, knees and ankles remain aligned in the sagittal plane
Minimal to no movement is noted in lumbar spine | Dowel and hurdle remain parallel

2

Alignment is lost between hips, knees and ankles | Movement is noted in lumbar spine
Dowel and hurdle do not remain parallel



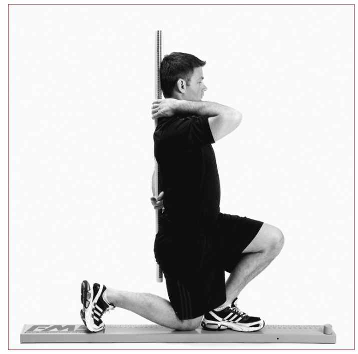
1

Contact between foot and hurdle occurs | Loss of balance is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

INLINE LUNGE

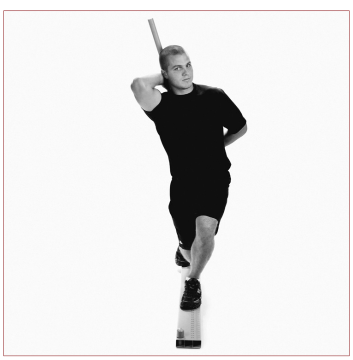
3



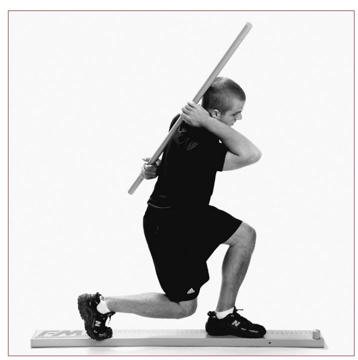
Dowel contacts maintained | Dowel remains vertical | No torso movement noted
Dowel and feet remain in sagittal plane | Knee touches board behind heel of front foot

2

Dowel contacts not maintained | Dowel does not remain vertical | Movement noted in torso
Dowel and feet do not remain in sagittal plane | Knee does not touch behind heel of front foot



1



Loss of balance is noted

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

SHOULDER MOBILITY

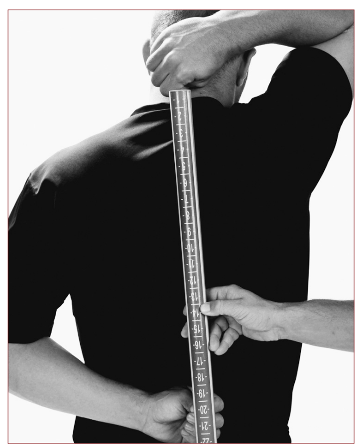
3

Fists are within one hand length

2

Fists are within one-and-a-half hand lengths

1



Fists are not within one and half hand lengths

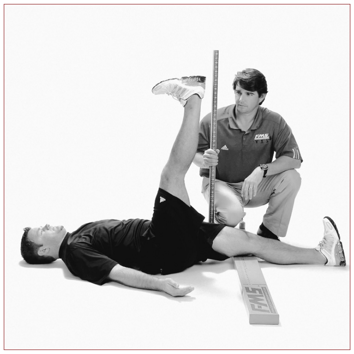
The athlete will receive a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.

Clearing Test

Perform this clearing test bilaterally. If the individual does receive a positive score, document both scores for future reference. If there is pain associated with this movement, give a score of zero and perform a thorough evaluation of the shoulder or refer out.

ACTIVE STRAIGHT-LEG RAISE

3

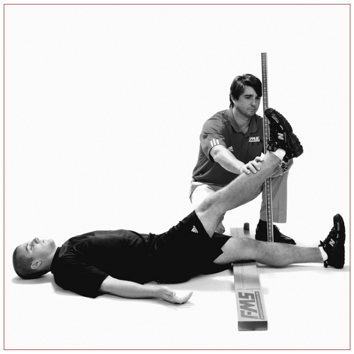


Vertical line of the malleolus resides between mid-thigh and ASIS
The non-moving limb remains in neutral position

2

Vertical line of the malleolus resides between mid-thigh and joint line
The non-moving limb remains in neutral position

1



Vertical line of the malleolus resides below joint line
The non-moving limb remains in neutral position

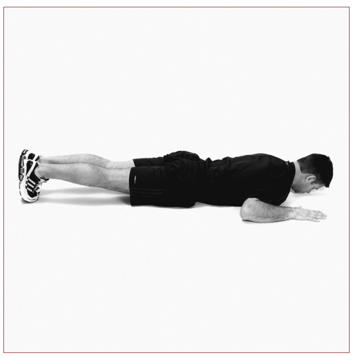
The athlete will receive a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.

TRUNK STABILITY PUSHUP

3

The body lifts as a unit with no lag in the spine

Men perform a repetition with thumbs aligned with the top of the head
Women perform a repetition with thumbs aligned with the chin



2

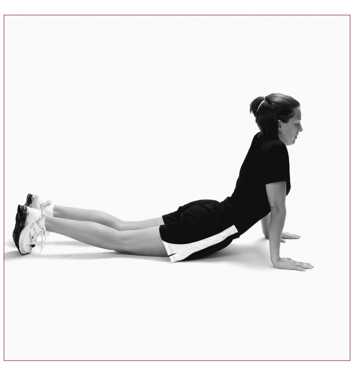
The body lifts as a unit with no lag in the spine
Men perform a repetition with thumbs aligned with the chin | Women with thumbs aligned with the clavicle

1

Men are unable to perform a repetition with hands aligned with the chin

Women unable with thumbs aligned with the clavicle

The athlete receives a score of zero if pain is associated with any portion of this test.
A medical professional should perform a thorough evaluation of the painful area.



Spinal Extension Clearing Test

Spinal extension is cleared by performing a press-up in the pushup position. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual does receive a positive score, document both scores for future reference.

Excerpted from the book, Movement: Functional Movement Systems—Screening, Assessment, Corrective Strategies

3

Performs a correct unilateral repetition

2

Performs a correct diagonal repetition

1

Inability to perform a diagonal repetition

The athlete receives a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.

Spinal Flexion Clearing Test

Spinal flexion can be cleared by first assuming a quadruped position, then rocking back and touching the buttocks to the heels and the chest to the thighs. The hands should remain in front of the body, reaching out as far as possible. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual receives a positive score, document both scores for future reference.

Project FLAME

Project FLAME - Perceived Motor Competence - Pre Test

* 1. What is your first name?

* 2. What is your surname?

* 3. What is your ID code (MF123, for example)?

* 4. What is your date of birth?

Date

Date

DD/MM/YYYY

* 5. What school are you in?

- Undisclosed
- Undisclosed
- Undisclosed

* 6. What year are you in?

- First Year
- Second Year
- Third Year

Project FLAME

Project FLAME - Perceived Motor Competence - Pre Test

Fundamental Movement Skills (FMS)

* 7. Based on your experience of having tried each skill during testing, use the scale below (1-10) to indicate how confident you are to correctly perform each skill:

1 = Not confident at all
5 = Somewhat confident
10 = Very Confident

	1	2	3	4	5	6	7	8	9	10
Run in a straight line	○	○	○	○	○	○	○	○	○	○
Skip in a straight line	○	○	○	○	○	○	○	○	○	○
Jump in the air for height from standing still	○	○	○	○	○	○	○	○	○	○
Jump for distance from standing still	○	○	○	○	○	○	○	○	○	○
Throw a tennis ball overarm	○	○	○	○	○	○	○	○	○	○
Catch a tennis ball using two hands	○	○	○	○	○	○	○	○	○	○
Kick a ball placed in front of you on the ground	○	○	○	○	○	○	○	○	○	○
Strike a non-moving ball placed in front of you at hip height with a bat	○	○	○	○	○	○	○	○	○	○
Bounce a ball with your hand four times in a row while standing	○	○	○	○	○	○	○	○	○	○
Balance on one foot	○	○	○	○	○	○	○	○	○	○

Project FLAME - Perceived Motor Competence - Pre Test

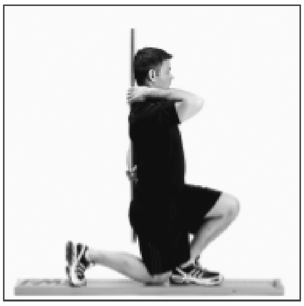
Functional Movement Screen (FMS™)

* 8. The picture(s) alongside each movement show a perfect performance of the movement.

Based on your experience of having tried each movement during testing, use the scale below (1-10) to indicate how confident you are to correctly perform each movement:

1 = Not confident at all
5 = Somewhat confident
10 = Very Confident

	1	2	3	4	5	6	7	8	9	10
Active Straight Leg Raise 										
Deep Squat  										

	1	2	3	4	5	6	7	8	9	10
Hurdle Step  	○	○	○	○	○	○	○	○	○	○
In-Line Lunge  	○	○	○	○	○	○	○	○	○	○

	1	2	3	4	5	6	7	8	9	10
Rotary Stability  										
Shoulder Mobility 										
Trunk Stability Push-Up 										

Project FLAME - Perceived Motor Competence - Post Test

* 1. What is your first name?

* 2. What is your surname?

* 3. What is your ID code (MF123, for example)?

* 4. What is your date of birth?

Date

Date

DD/MM/YYYY

* 5. What school are you in?

- Undisclosed
- Undisclosed
- Undisclosed

* 6. What year are you in?

- First Year
- Second Year
- Third Year

Project FLAME - Perceived Motor Competence - Post Test

Fundamental Movement Skills (FMS)

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Run in a straight line										
Skip in a straight line										
Jump in the air for height from standing still										
Jump for distance from standing still										
Throw a tennis ball overarm										
Catch a tennis ball using two hands										
Kick a ball placed in front of you on the ground										
Strike a non-moving ball placed in front of you at hip height with a bat										
Bounce a ball with your hand four times in a row while standing										
Balance on one foot										

Project FLAME

Project FLAME - Perceived Motor Competence - Post Test

Functional Movement Screen (FMS™)

* 8. The picture(s) alongside each movement show a perfect performance of the movement.

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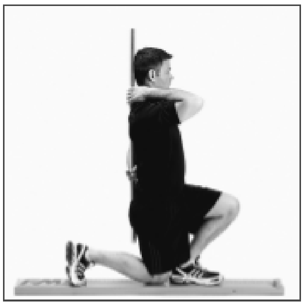
	1	2	3	4	5	6	7	8	9	10
Active Straight Leg Raise 	○	○	○	○	○	○	○	○	○	○
Deep Squat  	○	○	○	○	○	○	○	○	○	○

	1	2	3	4	5	6	7	8	9	10
Hurdle Step										

Hurdle Step

	1	2	3	4	5	6	7	8	9	10
In-Line Lunge										

In-Line Lunge



	1	2	3	4	5	6	7	8	9	10
Rotary Stability  										
Shoulder Mobility 										
Trunk Stability Push-Up 										

Appendix D:

Project FLAME Intervention Material

D1	Intervention Timetable and Class List Template
D2	Project FLAME: Physical Education Resource Cards
D3	Project FLAME Intervention: YouTube Links
D4	Project FLAME: Digital Resource Cards
D5	Kinaesthetic Classroom Movement Breaks: QR Codes
D6	Seomra Ranga Cinéistéiseacha: Cóid MF

Teacher Name

Class Name

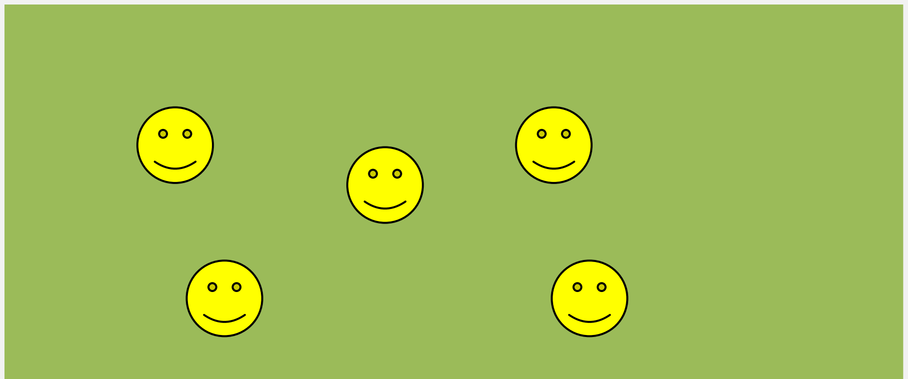
		Intervention Timetable												
First Name	**Surname**	27/11 - Balance	04/12 - Catch	11/12 - Deep Squat	18/12 - Dribble	08/01 - Horizontal Jump	15/01 - In-Line Lunge / Rotary Stability	22/01 - Kick	29/01 - Run	05/02 - Shoulder Mobility / Active Straight Leg Raise	19/02 - Skip	26/02 - Strike	05/03 - Throw	12/03 - Vertical Jump

Project FLAME: Physical Education Resource Cards

Teacher Manual

BALANCE

Basic Station



2 https://www.youtube.com/watch?v=2dbm32CHla0

3 https://www.youtube.com/watch?v=4DVgUfpYYeQ

4 https://www.youtube.com/watch?v=4rKO1byt9RQ

Challenge students to try the following activities with their eyes closed and/or on their non-preferred leg.

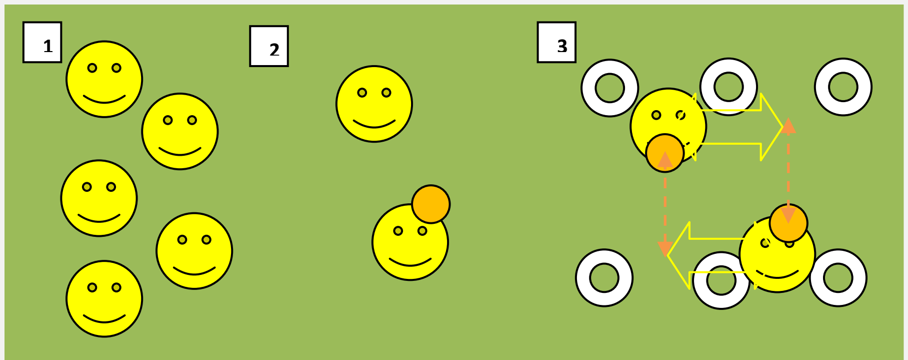
1) **Basic Balance.**

2) **Balance and Arm Movements.**

3) **Balance and Object Control.**

4) **Balance and Twist.**

Various Dynamic Progressions



1 https://www.youtube.com/watch?v=VhJvcv2eO_U

https://www.youtube.com/watch?v=Bjr-NImdaB4

2 https://www.youtube.com/watch?v=VtZVi8aYwkQ

3 https://www.youtube.com/watch?v=BazXC_rKXMQ

Challenge students to develop their ability to maintain or regain static balance from unstable positions including flight and while catching an object.

1) **Basic Lateral Bound with Balance.**
Advanced Lateral Bound with Balance.

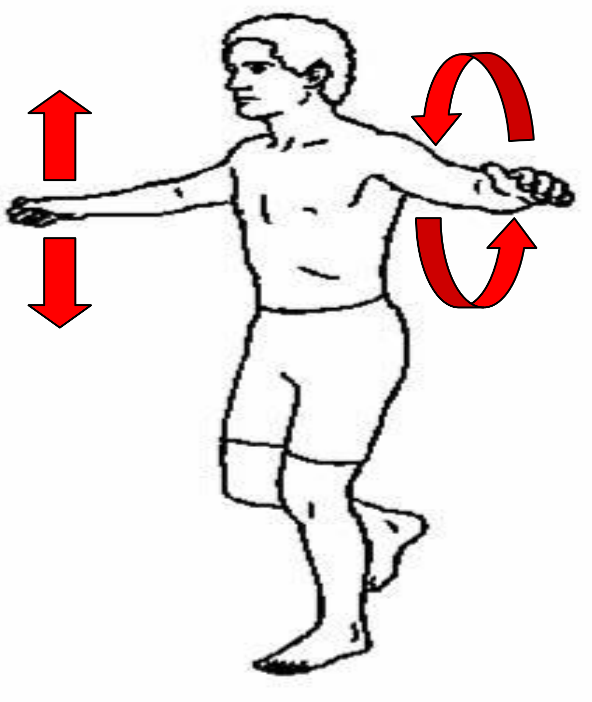
2) **Lateral Bound with Catch and Balance (Basic to Advanced).**

3) **Co-Operative Lateral Bound with Catch and Balance.**

BALANCE

Maintain a stable and upright trunk by engaging the core while arms are working.

Basic Balance



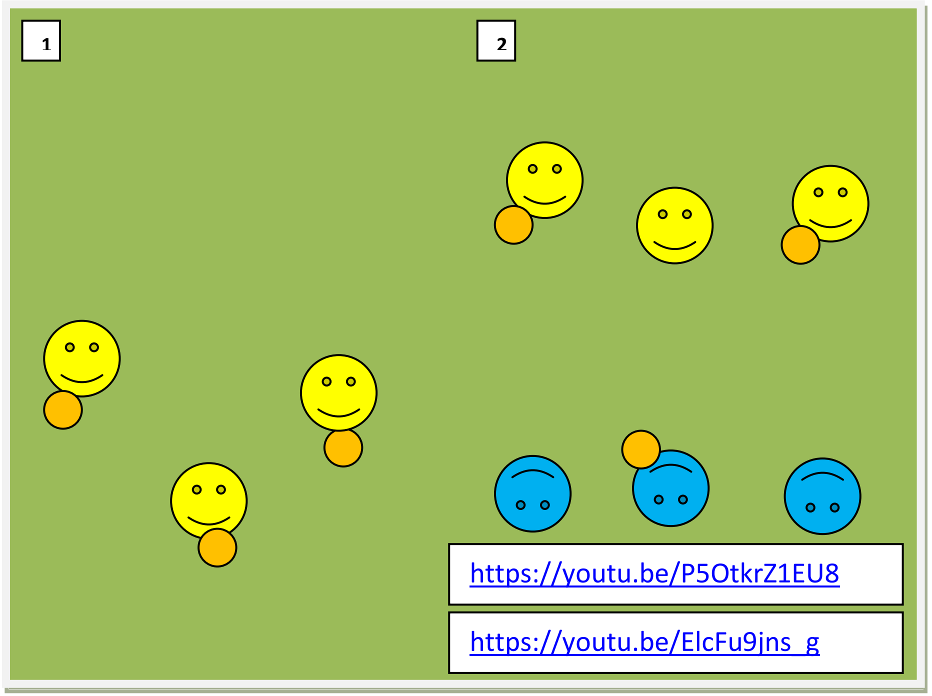
Lateral Bound

Progress from a 'Basic' to an 'Advanced' Lateral Bound by increasing the height and/or distance while maintaining balance (single leg) on landing.

BALANCE [GET SKILLED: GET ACTIVE]
(1) Standing leg still, foot flat on the ground.
(2) Non-standing leg bent back behind at the knee, not touching the standing leg.
(3) Head stable, eyes focused forward.
(4) Body stable and upright.
(5) Arms stretched out wide at the sides with no excessive movements.

CATCH

Basic Station



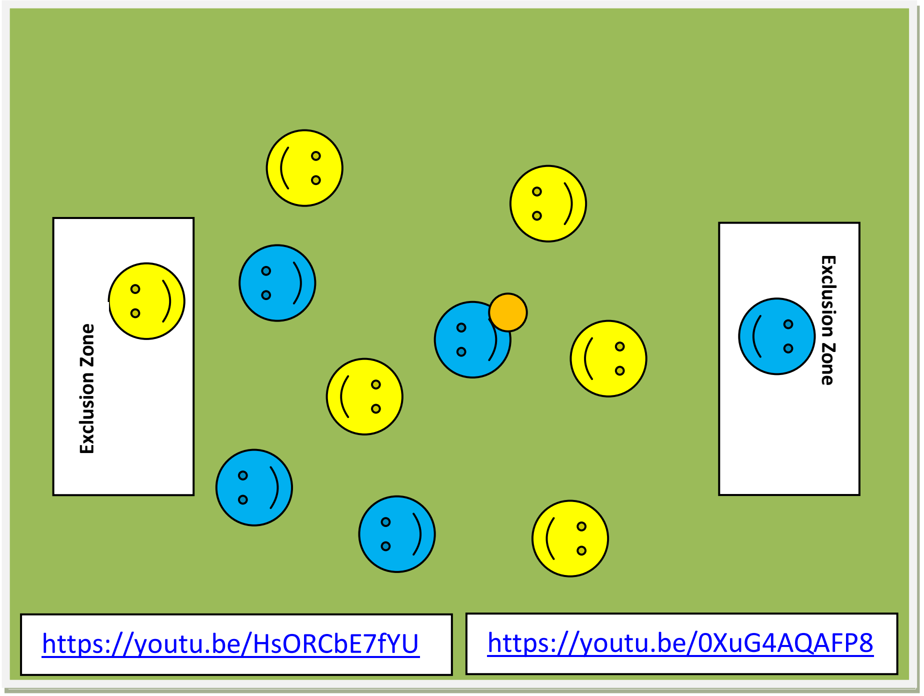
1) Students throw balls against the wall and catch the rebound.
2) Students work with a partner and take turns to throw and catch.

Students catch balls that are rolling and bouncing at varying speeds and heights.

Teaching cues:

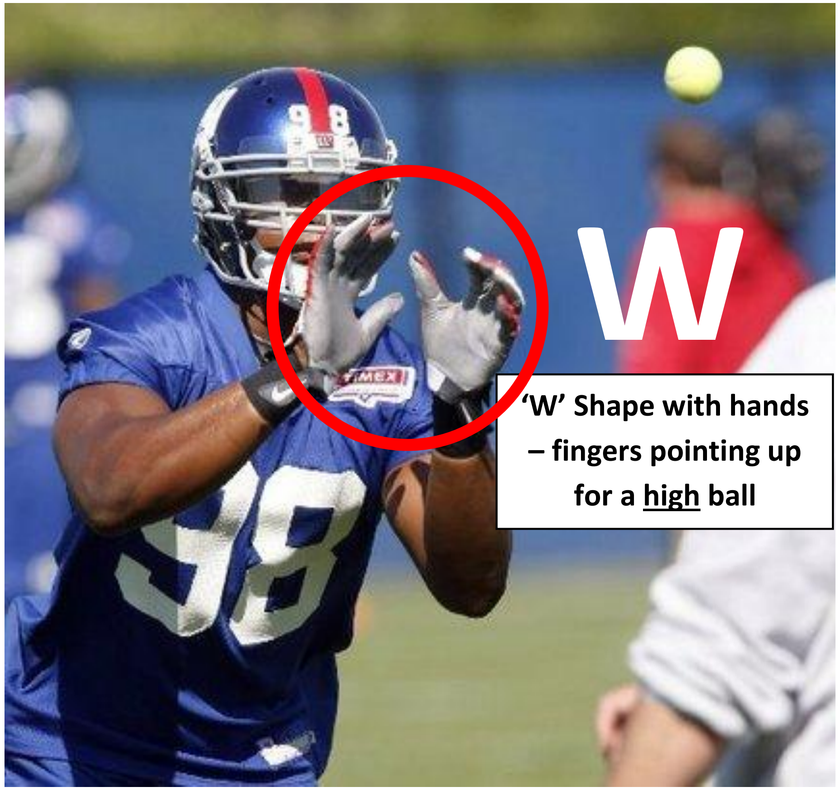
- Watch the object move into your hands.
- Move to the object.
- Relax your hands and soft fingers.
- Point your fingers up for a high ball – 'W' Shape.
- Point your fingers down for a low ball – 'M' Shape.
- Bend elbows to absorb the force of the object.

Progression



- Students throw [tennis] ball/beanbag/socks around the area using a two-hand catch only until they find an opening to throw the object to the player on their team in the exclusion zone. The player who threw the pass then swaps with the single player in the exclusion zone (<u>note</u>: a bench may be used instead if available in the Sports Hall).
- Students are not permitted to run when in possession of the object.
- There is no contact in this game although shadowing/screening and intercepting is permitted in order to regain possession.
- Option to use a soft larger object, as appropriate.

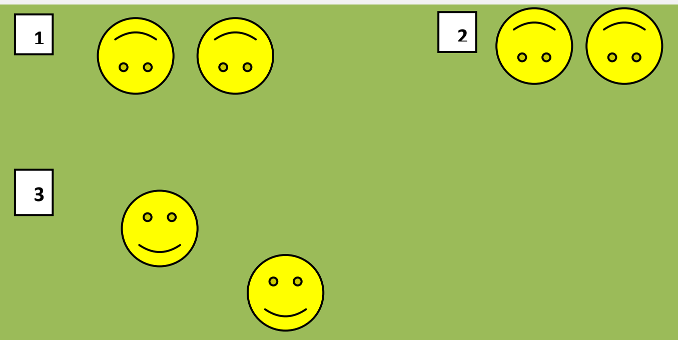
CATCH



CATCH [TGMD-2]
(1) Preparation phase where hands are in front of the body and elbows are bent.
(2) Arms reach out for the ball as it arrives.
(3) Ball is caught by both/two hands only.

DEEP SQUAT

Basic Station



1 https://www.youtube.com/watch?v=Ux_l4YSf23g

2 https://www.youtube.com/watch?v=0mxxIb2DG7I

3 https://www.youtube.com/watch?v=lBkGpaikTEA

4 https://www.youtube.com/watch?v=rn4-o1siTxc

Deep Squat preparatory movements and joint mobility:

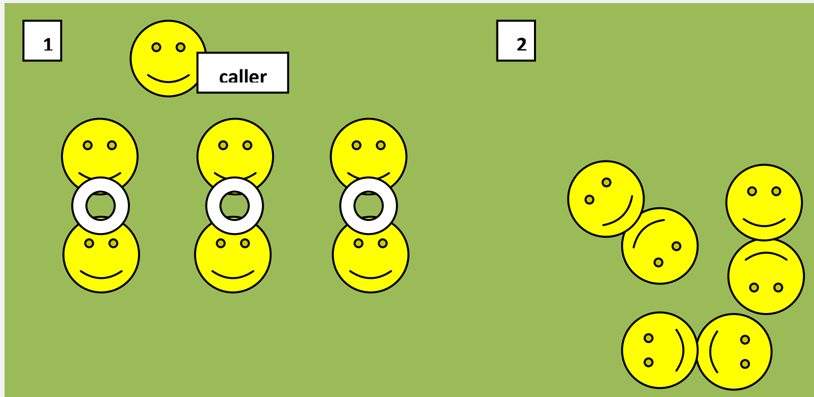
1) **Achilles Stretch (Ankle Mobility) for Deep Squat**

2) **Calf/Soleus Stretch for Deep Squat**

3) **Frog Squat**

4) **Bunny Hops**

Various Progressions



1 https://www.youtube.com/watch?v=alY2vG6Ayjk

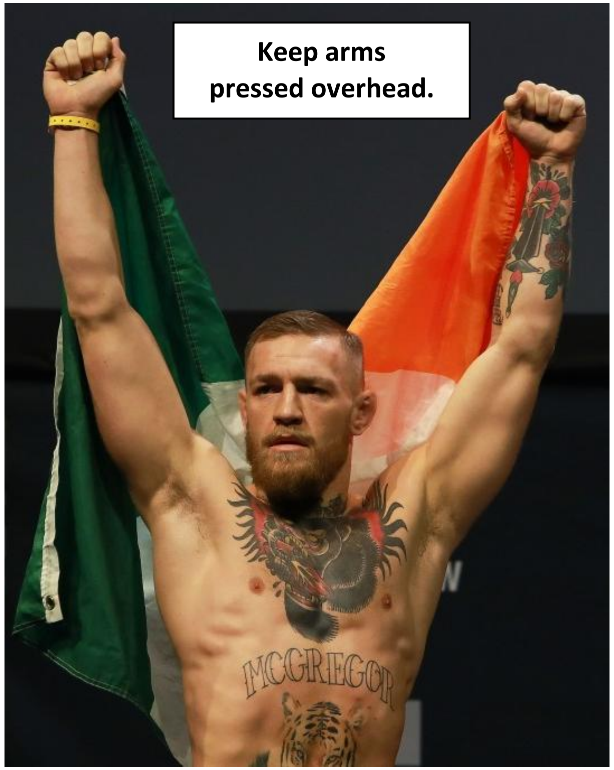
2 https://www.youtube.com/watch?v=unuM822xZ3M

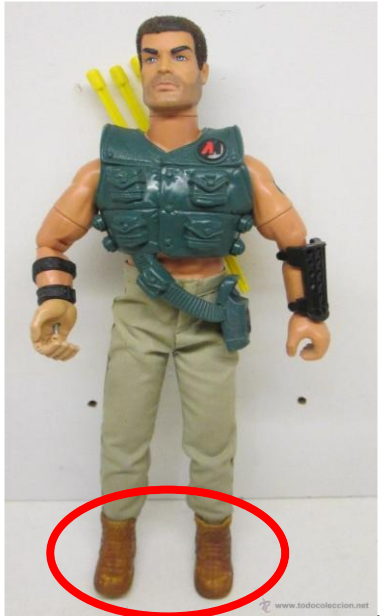
1) **<u>Deep Squat Cone Reaction Game</u>:** Students adopt a squat position facing a partner with a cone turned upside down between them. Maintaining the squat position, students are lead by the ‘caller’ who shouts different parts of the body which students must touch (for example, head, hips, toes, nose etc.) until the caller shouts cone and the quickest person of each pair to grab it gets a point.

2) **<u>Deep Squat Thumb War Game</u>:** Students move around the area and adopt a squat position to play a game of ‘Thumb War’ before moving on and repeating the same again.

DEEP SQUAT

Deep Squat





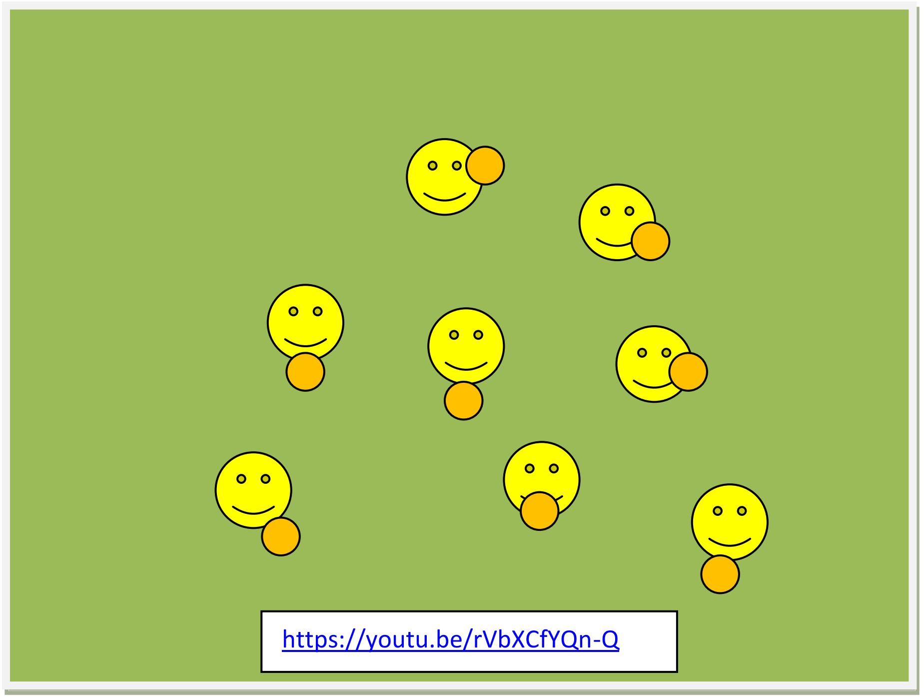
Toes pointing forward and shoulder width apart.

DEEP SQUAT
(1) Dowel fully pressed overhead and aligned over feet.
(2) Toes point forward.
(3) Knees aligned over feet and knees do not go passed the toe line.
(4) Thighs break parallel with the floor on the way down.

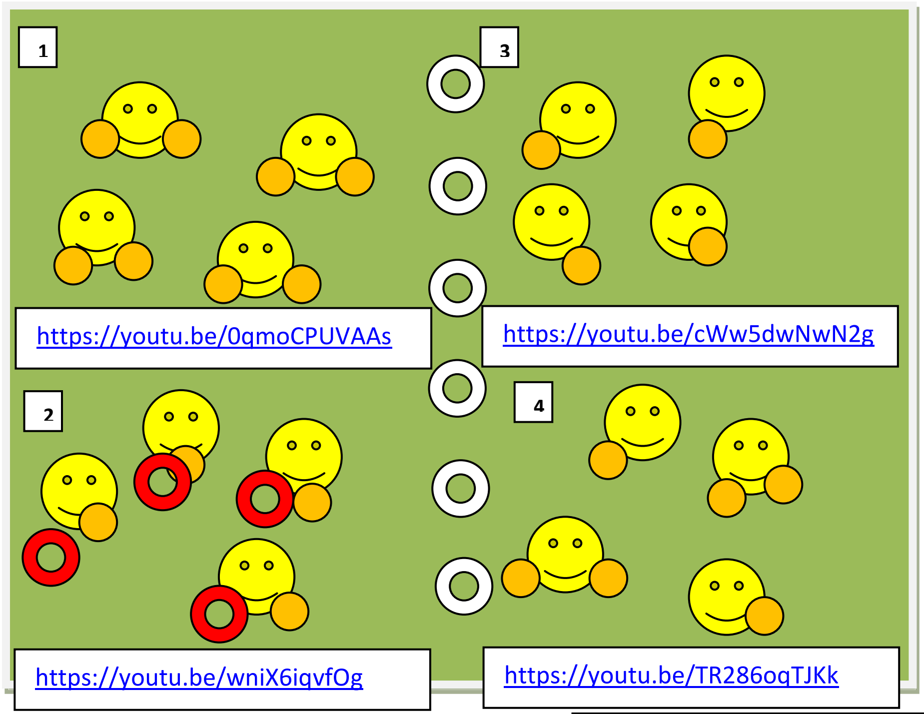
DRIBBLE

Project FLAME

Basic Station



Various Progressions



https://youtu.be/AKaJewgPiAI

Explore the dribble using a range of the following:

- What different parts of the hand can you use to dribble the ball ...
- How soft can you dribble the ball or how hard ...
- How low can you dribble the ball or how high ...
- How close to the body can you dribble the ball or how wide ...

1) Dribble two balls at the same time.

2) Dribble around the area and each time a student comes to a cone they do a full circle around the cone while maintaining control of the ball.

3) Dribble around the area changing direction only by dribbling ball through the legs (i.e. transferring ball from one hand to the other).

4) Dribble the ball while sitting flat using one ball or two.

DRIBBLE

Playing the piano - fingertips

How low can you go?

DRIBBLE [TGMD-2]
(1) Contacts ball with one hand at about waist level.
(2) Pushes ball with fingertips (not a slap).
(3) Ball contacts surface in front of or to the outside of foot on preferred side.
(4) Maintains control of ball for four bounces in a row without having to move the feet to retrieve it.

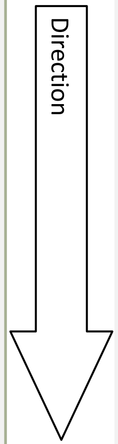
HORIZONTAL JUMP

Basic Station

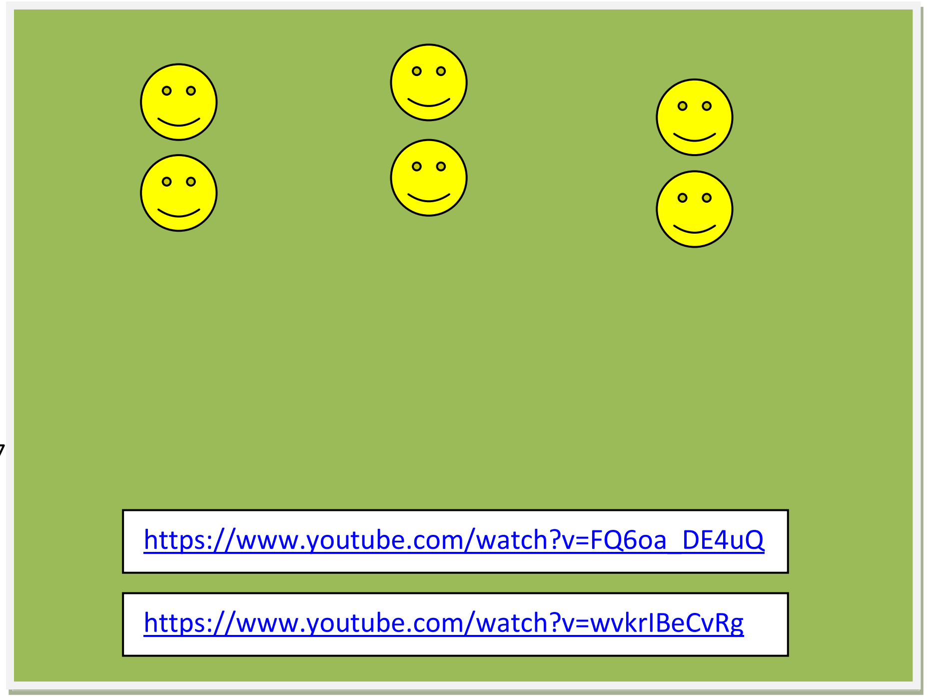
- Basic Horizontal Jump.

Explore the horizontal jump:

- experiment with different arm positions during the preparatory movement phase, flight phase and landing.



Progression



- Students work with a partner [of similar ability]. The aim of this progression is for the partner behind (who starts approximately half a meter behind i.e. out of touching distance) to tag the partner in front. The partner in front does a horizontal jump as far as possible and holds in position. The partner behind then does a horizontal jump and aims to reduce the distance between the partners after each jump and tag the partner in front after a set number of jumps and/or within a set distance.

HORIZONTAL JUMP

Landing phase

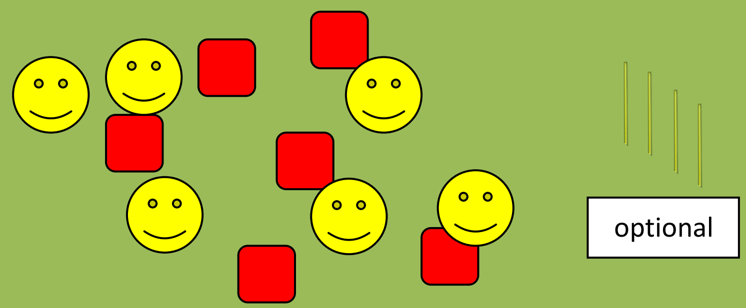
HORIZONTAL JUMP [TGMD-2]
(1) Preparatory movement includes bending of both knees with arms stretched out behind body.
(2) Arms reach forcefully forward and upward with full extension above the head.
(3) Take off and land on both feet together.
(4) Arms thrust downward during landing.

Flight phase

IN-LINE LUNGE & ROTARY STABILITY

Project FLAME

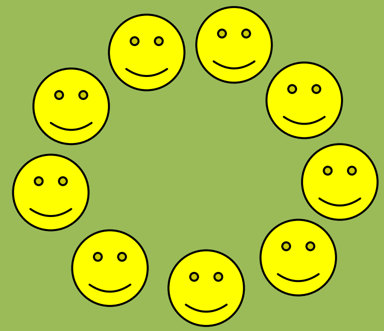
In-Line Lunge



1 https://www.youtube.com/watch?v=Nsr4sUuXL7s

2 https://www.youtube.com/watch?v=j4kk0byydeI

Rotary Stability



1 https://www.youtube.com/watch?v=niN8WpiZw0w

2 https://www.youtube.com/watch?v=JAnCUabgH98

3 https://www.youtube.com/watch?v=Yve-iHO6XyU

4 https://www.youtube.com/watch?v=7WMTRUqrydY

1) Beanbag Lunge 01

2) Beanbag Lunge 02

Explore different positions to place the beanbag during the lunge:

- below the knee that's lowering to the ground …
- on top of the head …
- on top of the brush handle or equivalent (as available) …

1) Spiderman Rotation 01

2) Spiderman Rotation 02

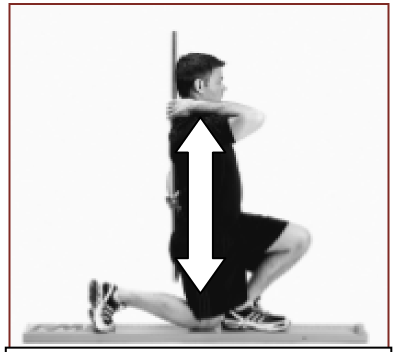
Complete 5-10 repetitions on both hands before switching leg positions.

3) Superman Kneeling

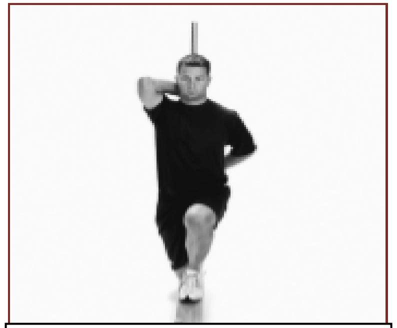
Complete 5-10 repetitions using opposite arm and leg (i.e. right arm stretched forward and left leg stretched back, then switch sides) before attempting same arm and leg.

4) Superman Standing

IN-LINE LUNGE & ROTARY STABILITY



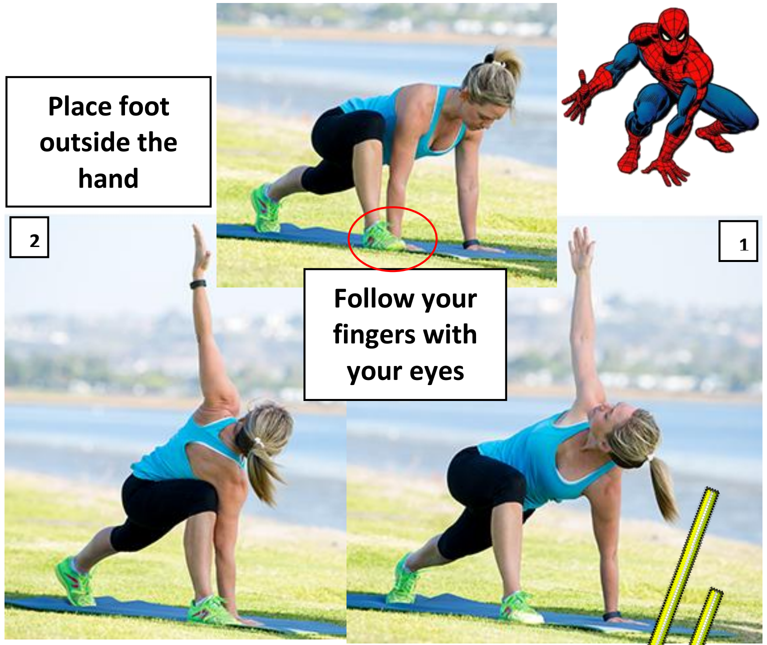
Keep body straight/upright



Keep both feet in-line

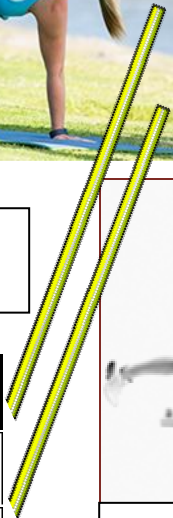
Eyes look straight ahead

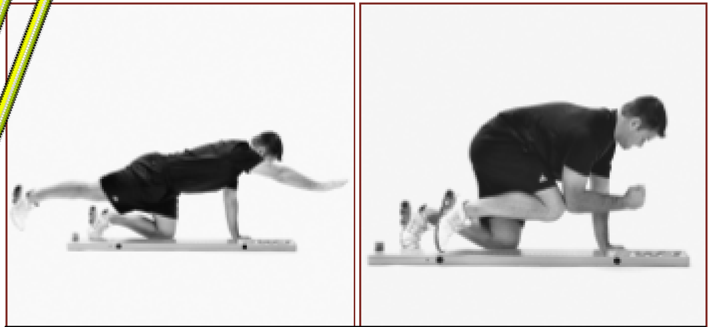
Place foot outside the hand



Follow your fingers with your eyes

Brush Handle or equivalent





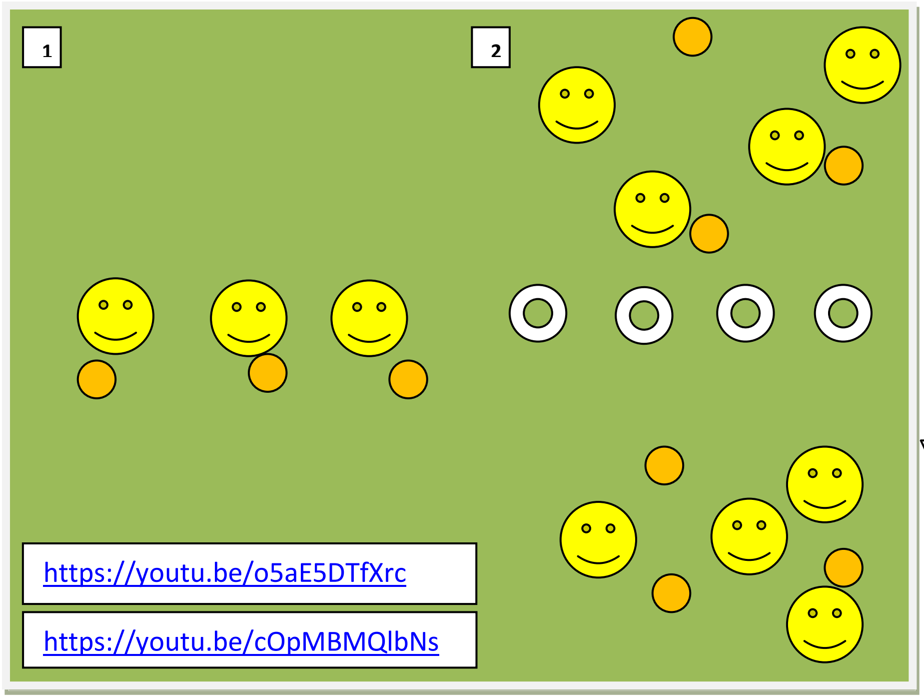
Same arm, same leg.

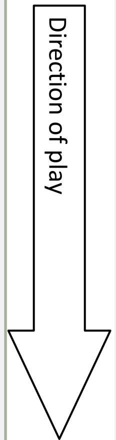
IN-LINE LUNGE
(1) Dowel remains in contact with head, [middle] back and backside.
(2) Dowel remains vertical.
(3) No body movement (i.e. balance is maintained).
(4) Knee touches board behind heel of front foot.
(5) The front heel remains in contact with the board and the back heel touches board when returning to starting position.

ROTARY STABILITY
(1) Ankles with toes tucked under (i.e. dorsiflexion).
(2) Back remains flat/parallel to board).

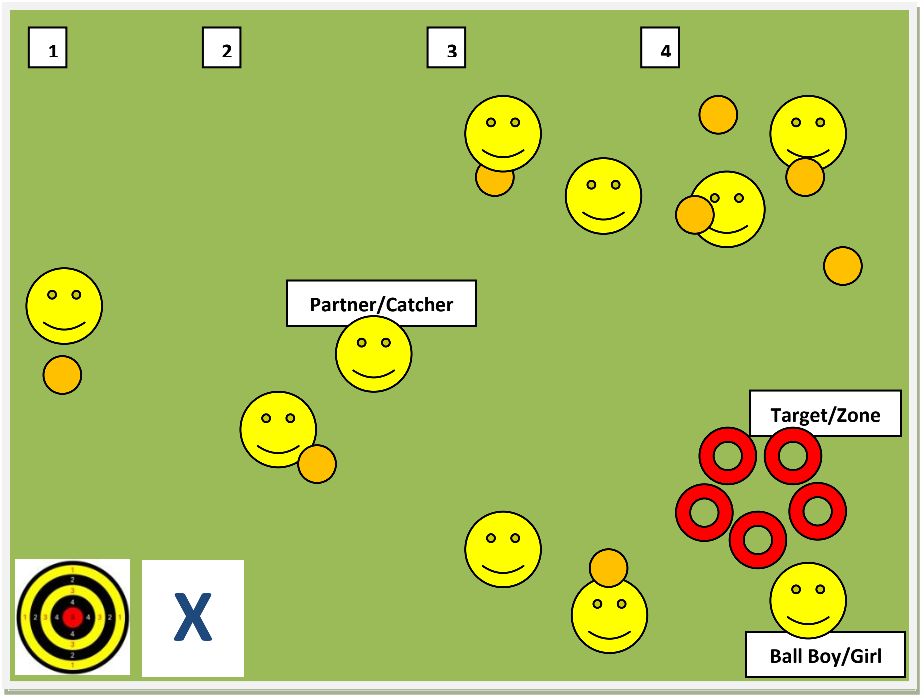
KICK

Basic Station





Various Progressions



1) Kick the ball as hard as possible at wall/partition or fence.

2) Kick the ball as hard and as far as possible from one side to the other. The aim is to kick the ball passed the group on the other side.

Explore the kick using a range of the following:

- approach the ball from directly behind and from an angle (i.e. from the side) to enable the kicking foot to follow through and touch the opposite hand.

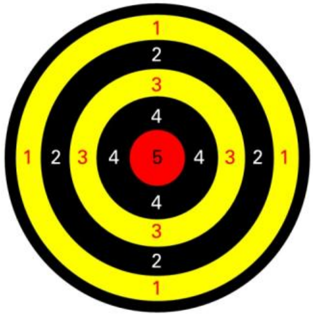
1) [Hall] Kick the ball forcefully at a target placed on the wall.

2) [Hall] Kick the ball forcefully at the wall and attempt to land the rebound in the hands of a partner who cannot move their feet.

3) [Hall/Field] Kick the ball to a partner standing at a distance (i.e. to encourage forceful kicking and accuracy as opposed to a short pass).

4) [Hall/Field] Kick the ball forcefully at a target placed on the ground at a distance (note: the aim is to land the ball in the target/zone rather than have the ball roll/bounce into the target).

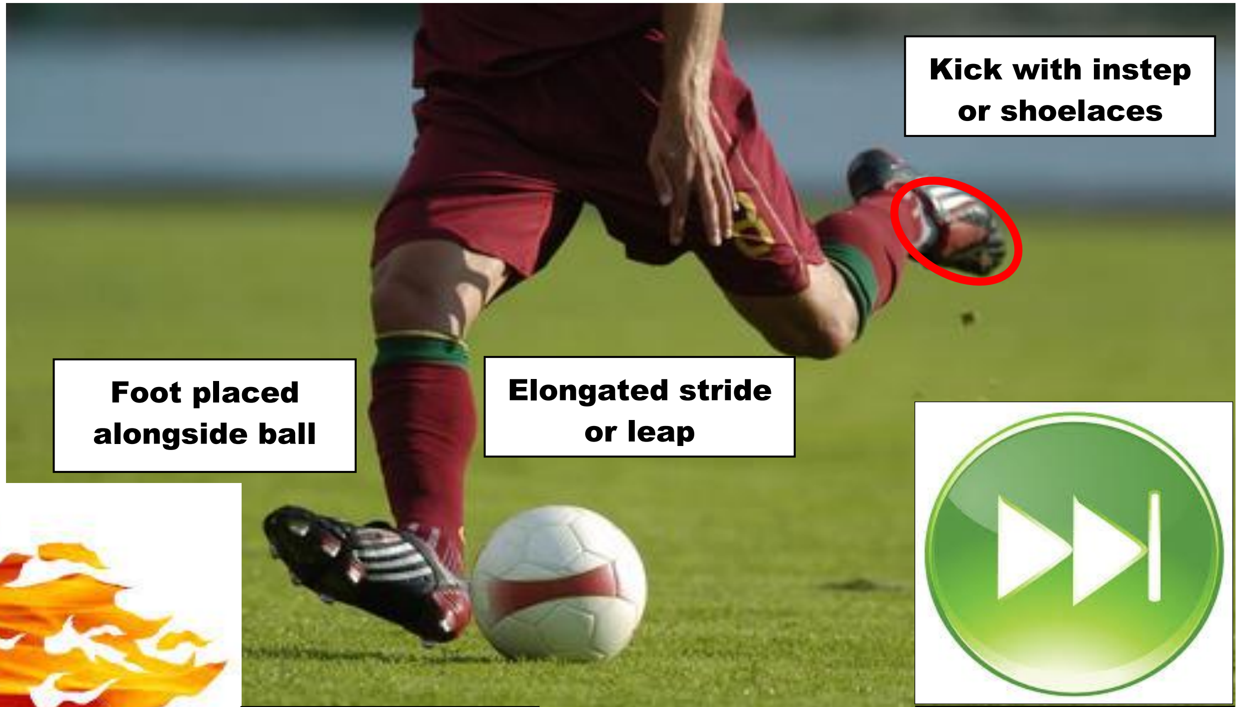
KICK



Use soft balls to encourage forceful kicking without risk of injury.
These balls won't travel very far.

1

Place ball on top of cone to encourage kicking with instep or shoelaces (optional).



Kick for power or distance

Fast forward on approach to ball

KICK [TGMD-2]
(1) Rapid continuous approach to the ball.
(2) An elongated stride or leap immediately prior to ball contact.
(3) Non-kicking foot placed even with (to the side) or slightly behind the ball.
(4) Kicks ball with instep of preferred foot (shoelaces) or toe.

RUN

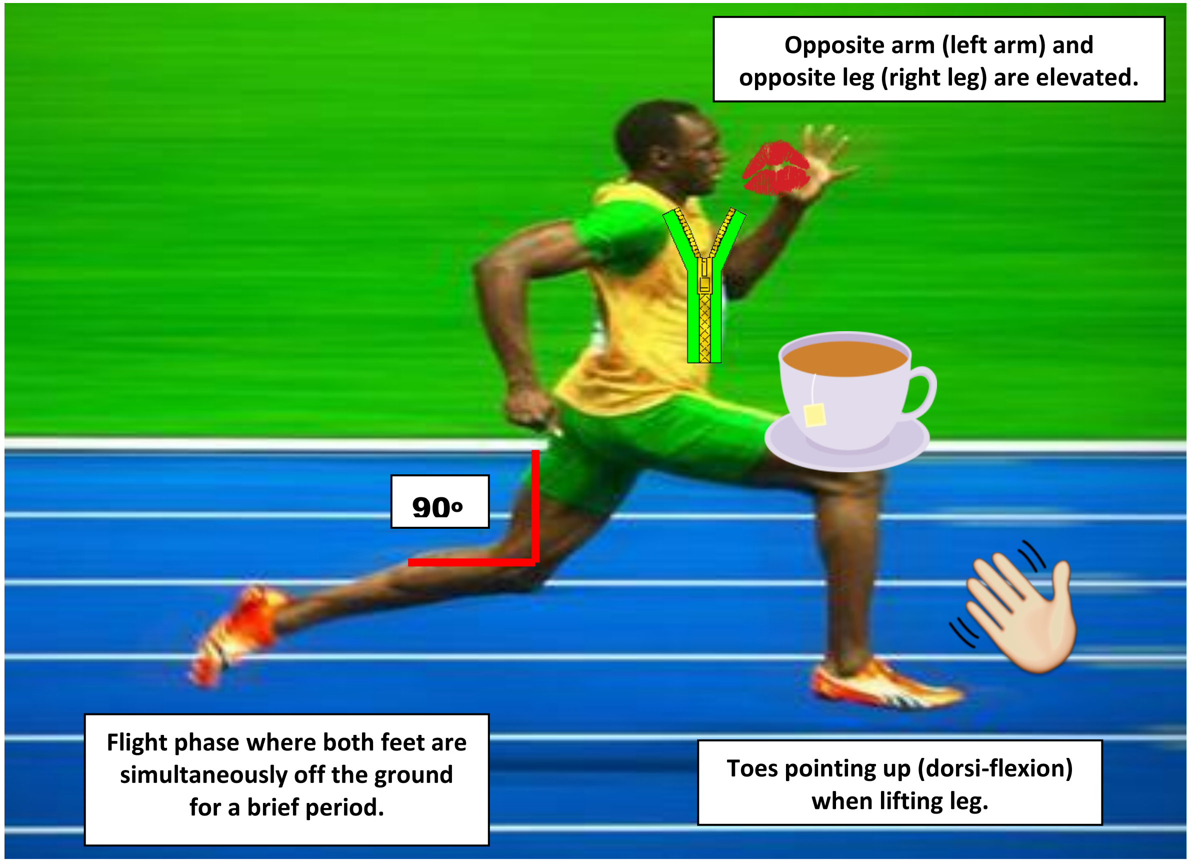
Basic Station

Various Progressions

- Run as fast as possible (sprint) for a distance of 10m – 20m.
- Students should land on the ball of their foot when sprinting.
- Run while focussing on specific body parts (legs, hands and head) as cued.

1) Marching for a distance of 10m – 20m exaggerating a sprinting technique as cued.
2) Students place both hands on the wall in front of them and adopt an exaggerated sprinting position facing the wall (i.e. one knee lifted with toes pointing up, chin facing forward, and on the ball of the standing foot). On the leader's call of 'go', students react and switch and hold in position for the next 'go'

RUN



RUN [TGMD-2]
(1) Arms alternately moving in opposition to legs, elbows bent.
(2) Brief period where both feet are off the ground.
(3) Narrow foot placement landing on heel or toe.
(4) Non-standing leg bent approximately 90 degrees.

LEGS

'Cup of tea up on the knee'

'Hello toe'

HANDS

'Hip to lip don't cross the zip'

HEAD

'Sort the chin and you will win'

ACTIVE STRAIGHT LEG RAISE & SHOULDER MOBILITY

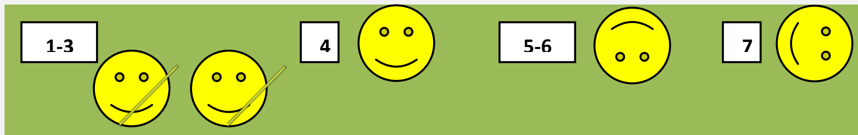
Active Straight Leg Raise

https://www.youtube.com/watch?v=V3pB7WUSPoA

Hamstring Assisted Partner Stretch (Doorframe).

- One student lies flat on the ground or mat as appropriate. The partner (standing) then holds one leg in place upright (<u>note</u>: This should not cause pain or discomfort to the student on the ground). The student on the ground then lifts the leg on the ground up next to the leg being held upright and lowers it down again in a slow but controlled fashion. Repeat. Focus on breathing into the stretch also. Swap legs then swap roles.

Shoulder Mobility

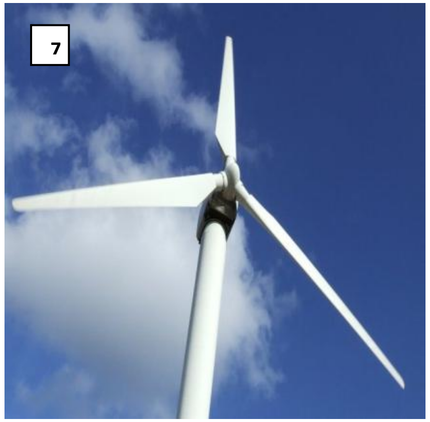


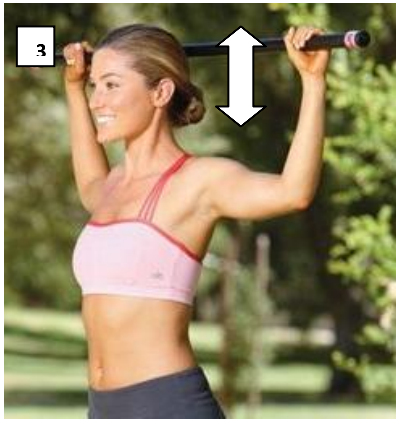
1. https://www.youtube.com/watch?v=c5uDW-xWzZo
2. https://www.youtube.com/watch?v=u2c3x-1o4Y0
3. https://www.youtube.com/watch?v=t2P0NWPtuTw
4. https://www.youtube.com/watch?v=sAIw7BDKRIY
5. https://www.youtube.com/watch?v=MeLIzYmYsMM
6. https://www.youtube.com/watch?v=RjKe-Giqjkg
7. https://www.youtube.com/watch?v=CQhSvVmELnw

1) Shoulder Mobility 01 (Front and Back)
2) Shoulder Mobility 02 (Rowing)
3) Shoulder Mobility 03 (Press Up and Pull Down)
4) Shoulder Mobility 04 (Wall Angel)
5) Shoulder Mobility 05 (Wall Slides)
6) Shoulder Mobility 06 (V Slides)
7) Shoulder Mobility 07 (Windmill)

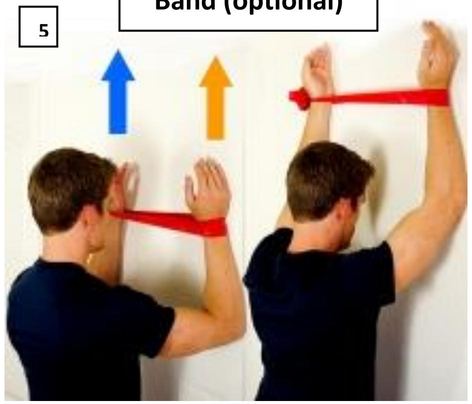
ACTIVE STRAIGHT LEG RAISE & SHOULDER MOBILITY

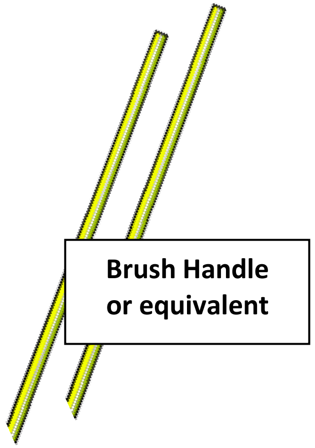
Place buttocks against doorframe
while the other leg is continuously lifting (dorsi-flexion)
and lowering (plantar-flexion) like a scissors.





Band (optional)



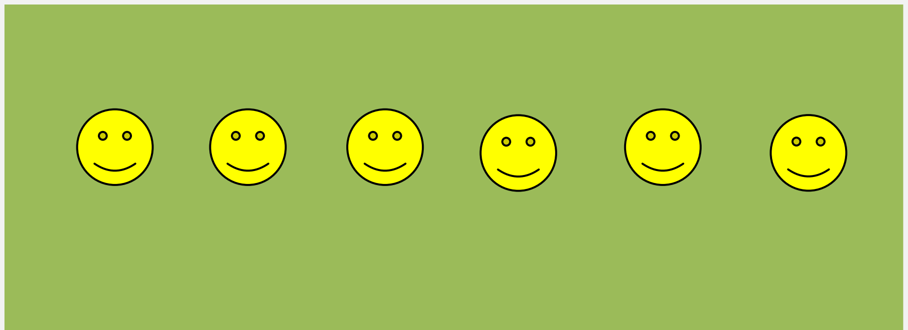


ACTIVE STRAIGHT LEG RAISE
(1) Knee on floor remains touching the ground.
(2) Leg on floor does not turn outwards at the hip.

SHOULDER MOBILITY
(1) Does not walk hands towards each other (i.e. one single motion).
(2) Head remains in neutral position (i.e. looking straight ahead).

SKIP

Basic Station



Basic March 01 – https://www.youtube.com/watch?v=yEf5LQ6CCT8

Basic March 02 – https://www.youtube.com/watch?v=Mqb4DX5wE5I

March into Skip – https://www.youtube.com/watch?v=jRR0svBmKzI

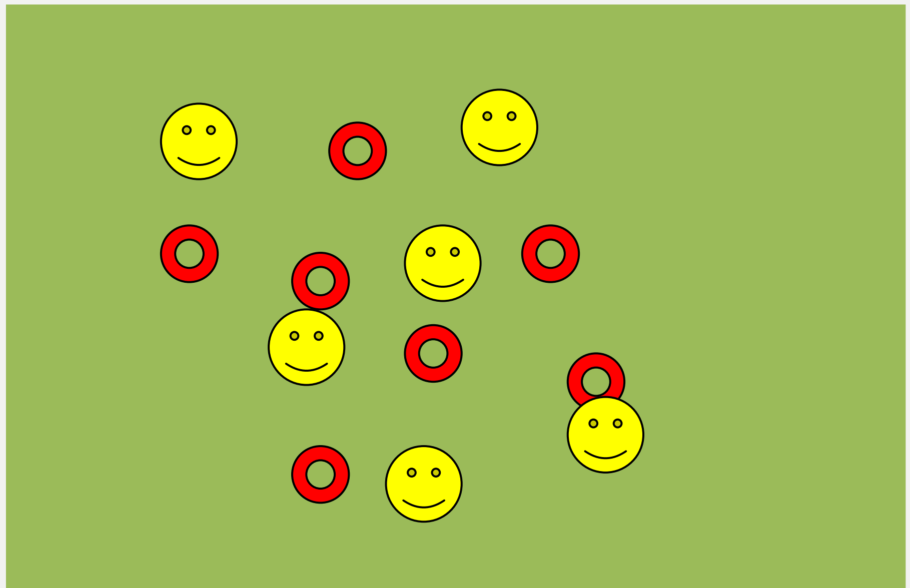
High Skip – https://www.youtube.com/watch?v=pWtROQ-mql8

- Students skip for a distance of 10m – 20m.

- Focus on the step-hop rhythm, rather than performing the movement with speed.
- Ensure the arms are alternately moving in opposition to legs.

Students explore the skip using a range of the following:
- different distances between steps.
- keep feet low.
- spring to gain height.
- different arm positions.

Progression



https://www.youtube.com/watch?v=A-OD3Rnn8T0

- Students move around the area by skipping only. They must skip over a cone as they come to it and maintain the step-hop skipping technique while avoiding contact with other members of the group.

- Have students develop skipping patterns, changing direction, length of step and height of hop.

SKIP

Arms alternately moving in opposition to legs.

Light springing steps

Step-hop rhythm

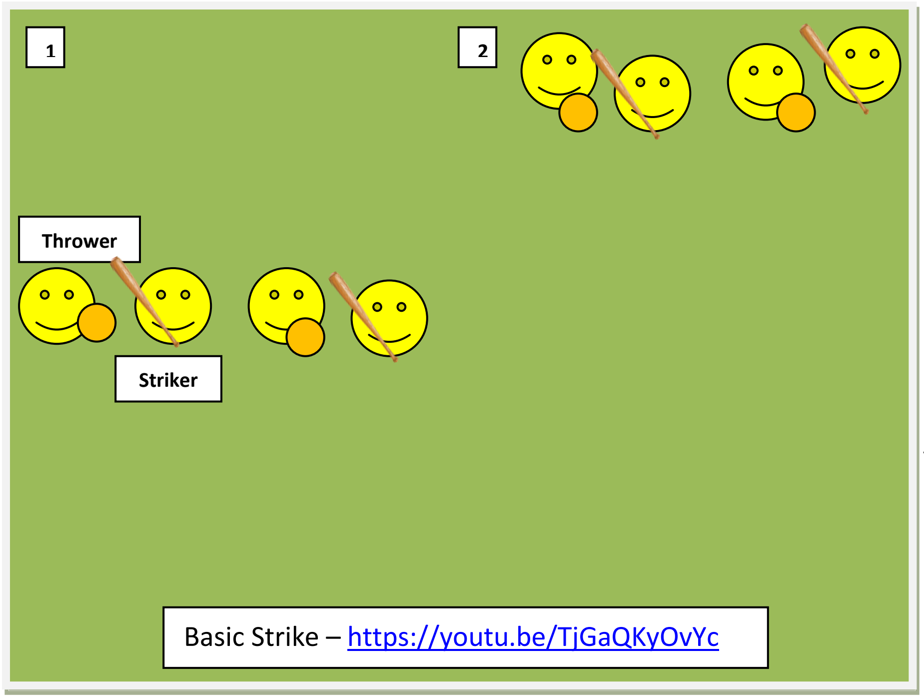
Arms swinging

Take off and land
on the front of your foot

SKIP [TGMD]
(1) A rhythmical repetition of the step-hop on alternate feet.
(2) Foot of non-standing leg carried near surface during the hop phase.
(3) Arms alternately moving in opposition to legs at about waist level.

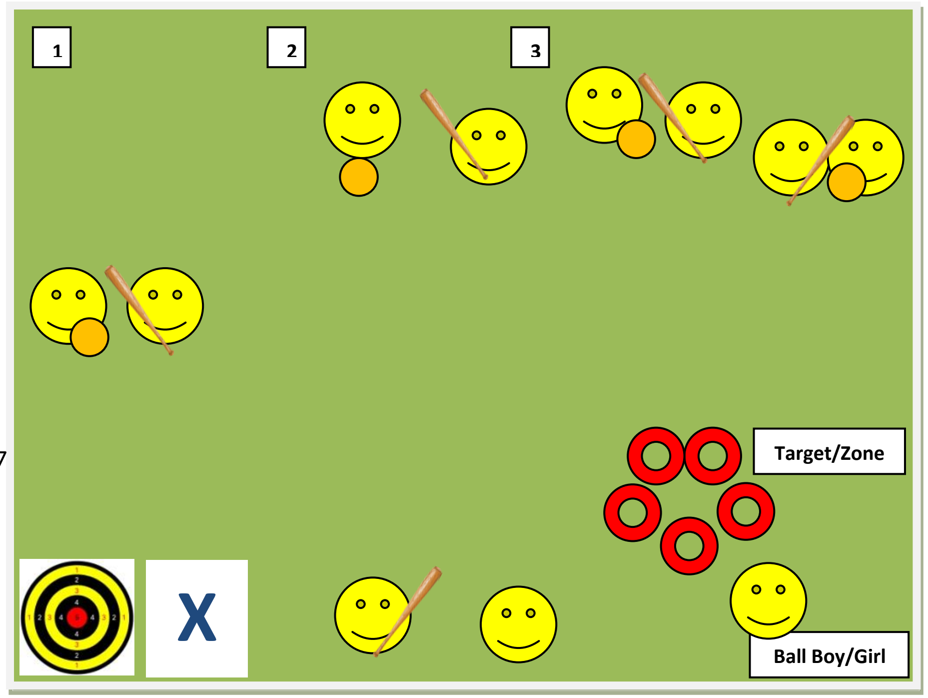
STRIKE

Basic Station



Direction of play

Various Progressions



1) Strike the object as hard as possible at wall, partition or fence.

2) Strike the object as hard and as far as possible.

Explore the strike using a range of the following:
- swing with both arms bent.
- swing with both arms straight.
- make a 'half swing' with no follow-through.
- try a full swing and follow-through.

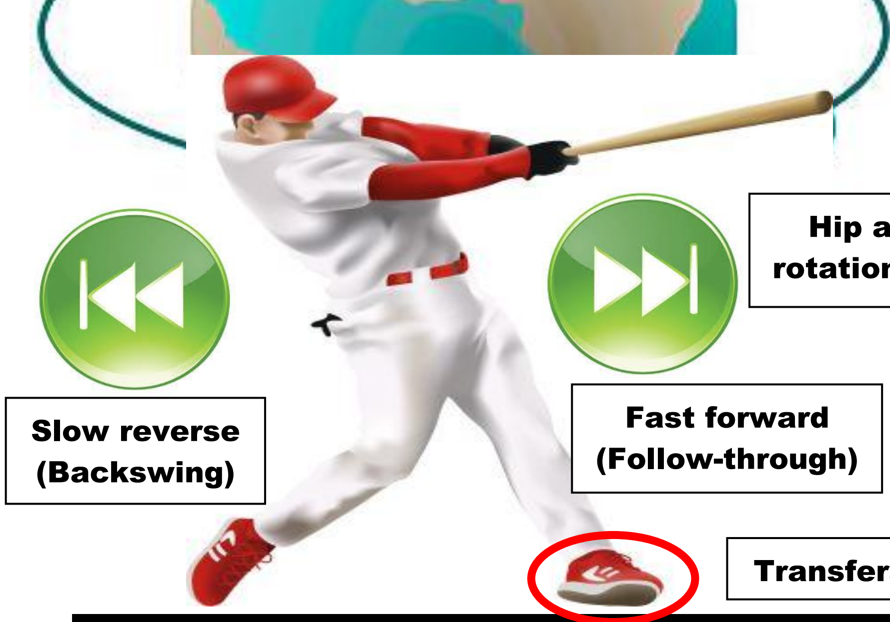
1) [Hall] Strike the object forcefully at a target placed on the wall.

2) [Field] Strike the object to a partner standing at a distance (i.e. to encourage forceful striking). The striker on one side is partnered with the catcher on the opposite side (who then becomes the thrower on that side) and swap roles.

3) [Field] Strike the object forcefully at a target/zone placed on the ground at a distance (note: the aim is to land the object in the target/zone rather than have the object roll/bounce into the target).

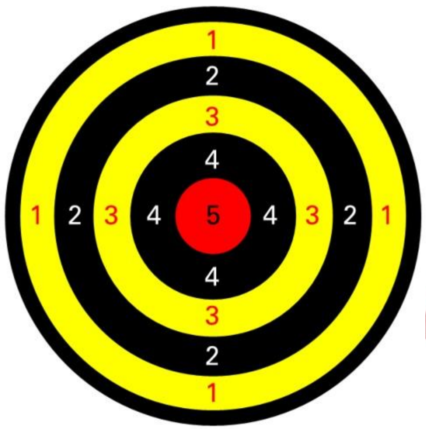
STRIKE

X marks the point of the backswing and the aim is to rotate around your body on the follow-through in order to touch the X mark again.



Ensure bats have a large surface area to facilitate successful attempts.
Use soft/larger objects to encourage forceful striking without the risk of injury.

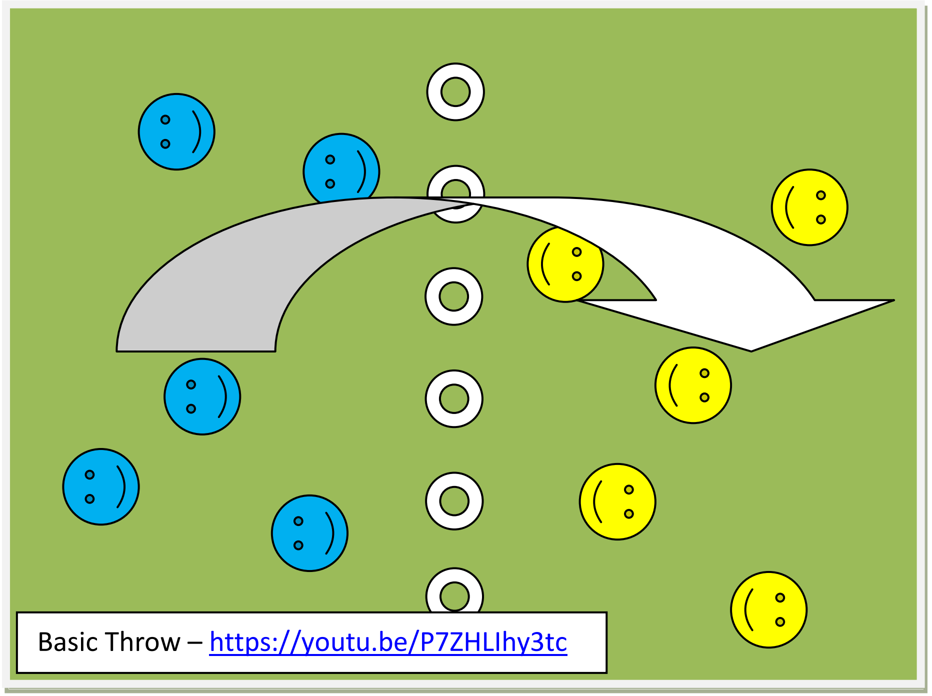
STRIKE [TGMD-2]
(1) Dominant hand grips bat above non-dominant hand (as the bat is pointing up).
(2) Non-preferred side of body faces the imaginary thrower with feet shoulder width apart.
(3) Hip and shoulder rotate/turn during swing.
(4) Transfers body weight to front foot.
(5) Bat contacts ball.



1

THROW

Basic Station



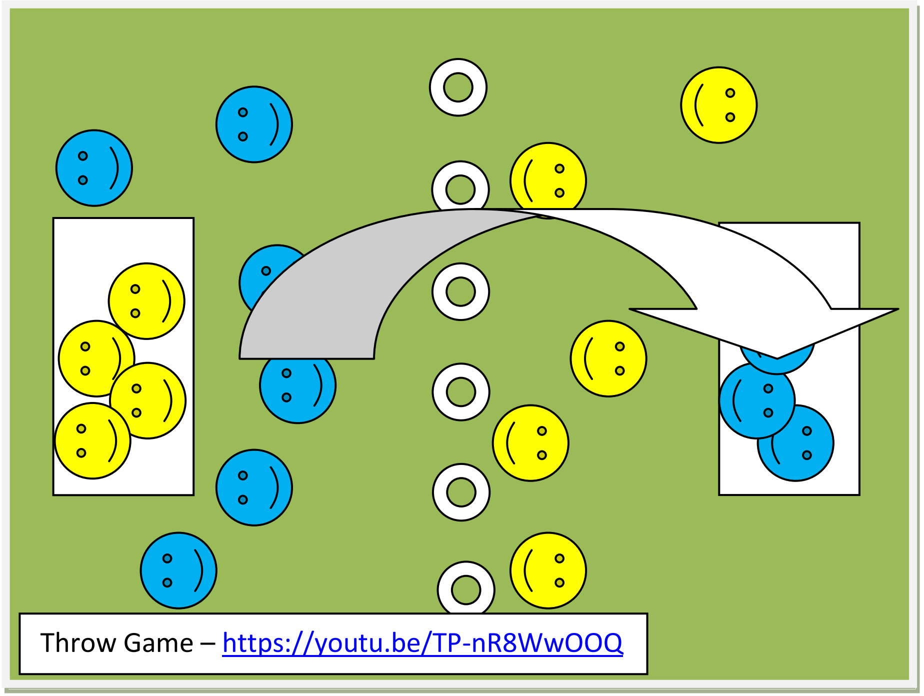
- Students throw beanbag/socks from one side to the other for distance.
- The speed and distance of the throw is determined by the follow-through.

Explore the throw using a range of the following:

- experiment with different hip, shoulder and feet movements as they throw.
- stand facing towards the target, keeping their hips and feet still.
- stand side-on and rotate their shoulders but not their hips.
- stand side-on and rotate hips and shoulders.
- take a small step as they throw to transfer their body weight.
- identify which position is the most efficient for distance and speed.

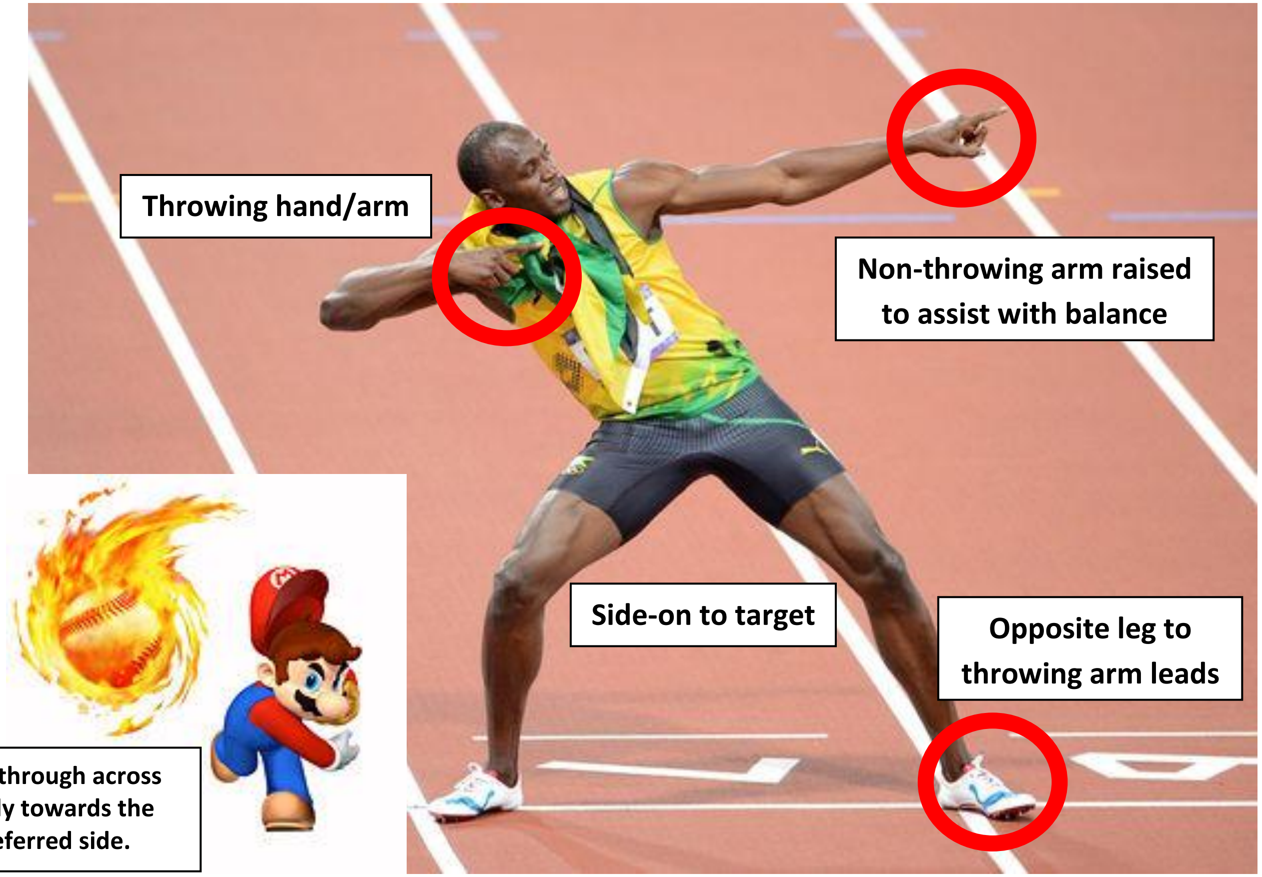
- Have students practice the throw from a sitting and kneeling position (optional).

Progression



- Students throw beanbag/socks from one side to the other trying to reach a member of their own team on the opposite side. This will free them from the box and allow them to rejoin their team.
- Students on the opposing team are not allowed into the box.
- Students may however also throw beanbag/socks at a member of the opposing team (below the waist) similar to the game of dodgeball.
- If hit, that student will then join their teammates in the box on the opposite side.

THROW



Follow-through across the body towards the non-preferred side.

Homemade resource enabling and empowering students

Show me the Nike logo using your arms ...

The most successful slogan in the world – 'Just Do It'

THROW [TGMD-2]
(1) Wind-up is initiated with downward movement of hand/arm.
(2) Rotates hip and shoulder to a point where the non-throwing side faces the wall.
(3) Weight is transferred by stepping with the foot opposite the throwing hand.
(4) Follow-through with hand beyond ball release diagonally across the body towards the non-preferred side.

VERTICAL JUMP

Basic Station

Encourage students to jump as high as possible.

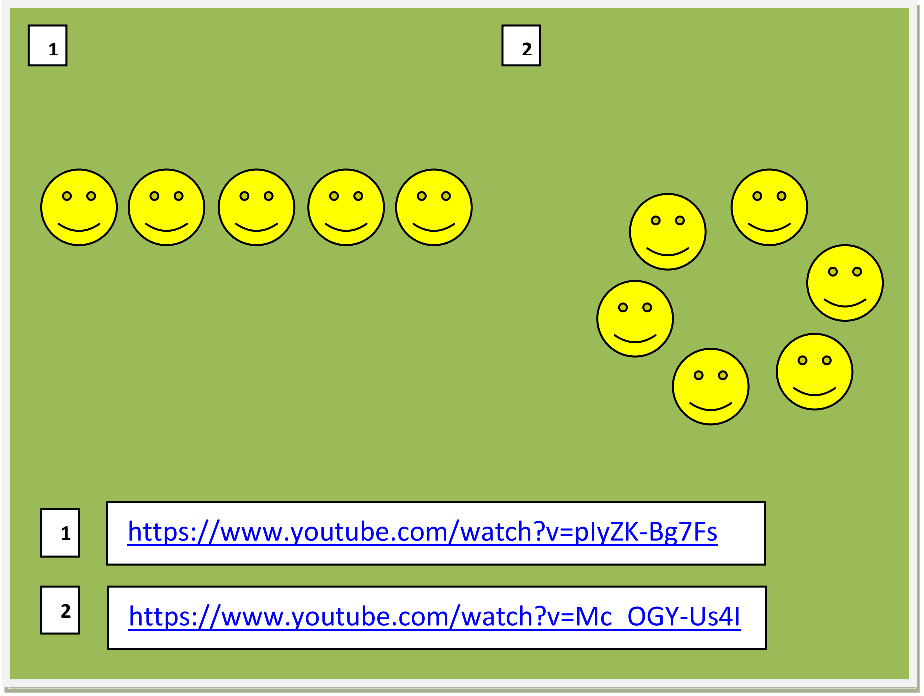
1) **Basic Vertical Jump**.

2) **Clap High Five (Vertical Jump)** to develop use arms.

3) **Landing Technique and Reaction** to develop control of landings.

4) **Vertical Jump 'Time'**: Students always begin the vertical jump by facing 12.00 o'clock. The aim is to jump, turn in the air and execute a controlled landing with feet both facing a set hour on the clock.

Various Progressions



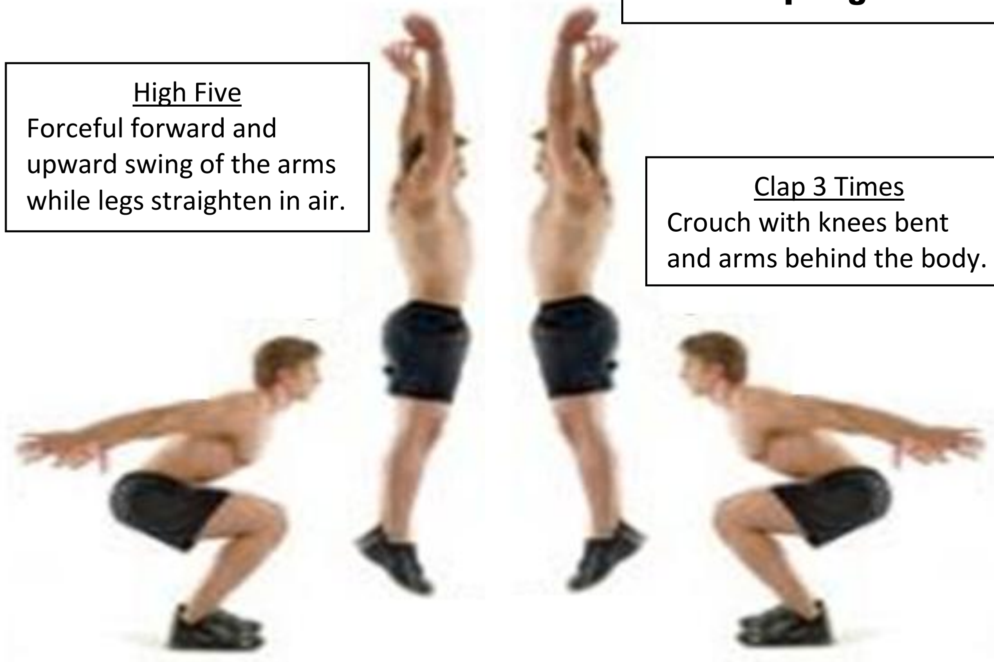
1) **Mexican Wave Vertical Jump**: Students line up in the aforementioned crouch position with knees bent and arms behind the body. A student at one end begins the 'Mexican Wave' by completing a vertical jump and the rest follow in suit like a domino effect.

2) **Mexican Wave Circle**: As above but this time students may change the direction of the 'Mexican Wave' by landing and facing in the opposite direction. The next student must try and react by using his/her peripheral vision while correctly executing the components of the vertical jump.

VERTICAL JUMP

Mexican Wave

Clap High Five



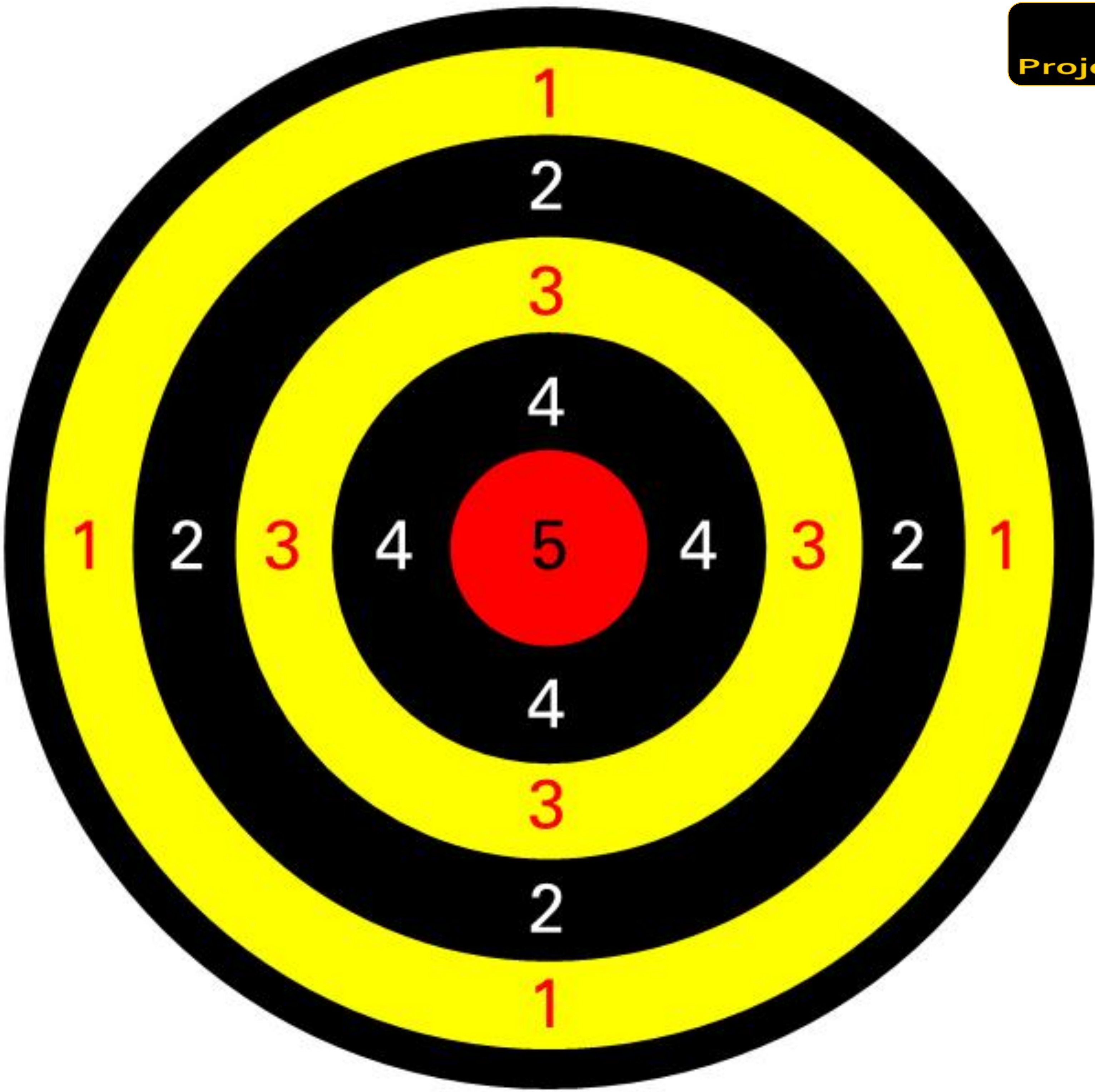
High Five
Forceful forward and upward swing of the arms while legs straighten in air.

Clap 3 Times
Crouch with knees bent and arms behind the body.

VERTICAL JUMP [GET SKILLED: GET ACTIVE]
(1) Eyes focused forward or upward throughout the jump.
(2) Crouch with knees bent and arms behind the body.
(3) Forceful forward and upward swing of the arms.
(4) Legs straighten in air.
(5) Land on balls of feet and bend knees to absorb landing.
(6) Controlled landing with <u><</u>1 step any direction.

Vertical Jump ‘Time’

Project FLAME



Project FLAME Intervention – YouTube Links

Active Straight Leg Raise

Hamstring Assisted Partner Stretch (Doorframe) – https://www.youtube.com/watch?v=V3pB7WUSPoA

Balance

Balance and Arm Movements – https://www.youtube.com/watch?v=2dbm32CHla0

Balance and Object Control – https://www.youtube.com/watch?v=4DVgUfpYYeQ

Balance and Twist – https://www.youtube.com/watch?v=4rKO1byt9RQ

Basic Lateral Bound with Balance – https://www.youtube.com/watch?v=VhJvcv2eO_U

Advanced Lateral Bound with Balance – https://www.youtube.com/watch?v=Bjr-NImdaB4

Lateral Bound with Catch and Balance (Basic to Advanced) – https://www.youtube.com/watch?v=VtZVi8aYwkQ

Co-Operative Lateral Bound with Catch and Balance – https://www.youtube.com/watch?v=BazXC_rKXMQ

Catch

Basic Catch – https://www.youtube.com/watch?v=P5OtkrZ1EU8

Advanced Catch – https://www.youtube.com/watch?v=ElcFu9jns_g

Catching Game 1 – https://www.youtube.com/watch?v=HsORCbE7fYU

Catching Game 2 – https://www.youtube.com/watch?v=0XuG4AQAFP8

Deep Squat

Achilles Stretch (Ankle Mobility) for Deep Squat – https://www.youtube.com/watch?v=Ux_l4YSf23g

Calf/Soleus Stretch for Deep Squat – https://www.youtube.com/watch?v=0mxxIb2DG7I

Frog Squat – https://www.youtube.com/watch?v=lBkGpaikTEA

Bunny Hops – https://www.youtube.com/watch?v=rn4-o1siTxc

Deep Squat Cone Reaction Game – https://www.youtube.com/watch?v=alY2vG6Ayjk

Deep Squat Thumb War Game – https://www.youtube.com/watch?v=unuM822xZ3M

Dribble

Basic Dribble – https://www.youtube.com/watch?v=rVbXCfYQn-Q

Double Dribble – https://www.youtube.com/watch?v=0qmoCPUVAAs

Cone Dribble – https://www.youtube.com/watch?v=wniX6iqvfOg

Legs Dribble – https://www.youtube.com/watch?v=cWw5dwNwN2g

Basic Seated Dribble – https://www.youtube.com/watch?v=TR286oqTJKk

Advanced Seated Dribble – https://www.youtube.com/watch?v=AKaJewgPiAI

Horizontal Jump

Basic Horizontal Jump 01 – https://www.youtube.com/watch?v=ktrRYSDUJNc

Basic Horizontal Jump 02 – https://www.youtube.com/watch?v=GFtqwm3r4Tk

Horizontal Jump Tag (Pair) – https://www.youtube.com/watch?v=FQ6oa_DE4uQ

Horizontal Jump Tag (Group) – https://www.youtube.com/watch?v=wvkrIBeCvRg

In-Line Lunge

Beanbag Lunge 01 – https://www.youtube.com/watch?v=Nsr4sUuXL7s

Beanbag Lunge 02 – https://www.youtube.com/watch?v=j4kk0byydeI

Kick

Basic Kick 1 – https://www.youtube.com/watch?v=o5aE5DTfXrc

Basic Kick 2 – https://www.youtube.com/watch?v=cOpMBMQlbNs

Rotary Stability

Spiderman Rotation 01 – https://www.youtube.com/watch?v=niN8WpiZw0w

Spiderman Rotation 02 – https://www.youtube.com/watch?v=JAnCUabgH98

Superman Kneeling – https://www.youtube.com/watch?v=Yve-iHO6XyU

Superman Standing – https://www.youtube.com/watch?v=7WMTRUqrydY

Run

Fun Runs – https://www.youtube.com/watch?v=4bcWgkbIj34

Running Technique – https://www.youtube.com/watch?v=gWA0w0sjFZQ

Left-Foot Strike – https://www.youtube.com/watch?v=NUBaGEygB_w

Right-Foot Strike – https://www.youtube.com/watch?v=wCOvjfg8crU

Exchange - https://www.youtube.com/watch?v=4EVNmwXTDEY

Shoulder Mobility

Shoulder Mobility 01 (Front and Back) – https://www.youtube.com/watch?v=c5uDW-xWzZo

Shoulder Mobility 02 (Rowing) – https://www.youtube.com/watch?v=u2c3x-1o4Y0

Shoulder Mobility 03 (Press Up and Pull Down) – https://www.youtube.com/watch?v=t2P0NWPtuTw

Shoulder Mobility 04 (Wall Angel) – https://www.youtube.com/watch?v=sAIw7BDKRIY

Shoulder Mobility 05 (Wall Slides) – https://www.youtube.com/watch?v=MeLIzYmYsMM

Shoulder Mobility 06 (V Slides) – https://www.youtube.com/watch?v=RjKe-Giqjkg

Shoulder Mobility 07 (Windmill) – https://www.youtube.com/watch?v=CQhSvVmELnw

Skip

Basic Marching Technique 01 – https://www.youtube.com/watch?v=yEf5LQ6CCT8

Basic Marching Technique 02 – https://www.youtube.com/watch?v=Mqb4DX5wE5I

March into Basic Skip – https://www.youtube.com/watch?v=jRR0svBmKzI

High Skip – https://www.youtube.com/watch?v=pWtROQ-mql8

Cone Skip – https://www.youtube.com/watch?v=A-OD3Rnn8T0

Strike

Basic Strike – https://www.youtube.com/watch?v=TjGaQKyOvYc

Throw

Basic Throw – https://www.youtube.com/watch?v=P7ZHLIhy3tc

Throwing Game – https://www.youtube.com/watch?v=TP-nR8WwOOQ

Vertical Jump

Basic Vertical Jump – https://www.youtube.com/watch?v=Z1fMk5vCsU0

Clap High Five (Vertical Jump) – https://www.youtube.com/watch?v=FpgDAWXJrNQ

Landing Technique and Reaction – https://www.youtube.com/watch?v=TkNwl6-wzMI

Mexican Wave Vertical Jump – https://www.youtube.com/watch?v=plyZK-Bg7Fs

Mexican Wave Circle – https://www.youtube.com/watch?v=Mc_OGY-Us4I

Project FLAME: Digital Resource Cards

Teacher Manual

Project FLAME

Balance

Co-Operative Lateral Bound with Catch and Balance

Balance and Arm Movements

Lateral Bound with Catch and Balance (Basic to Advanced)

Balance and Object Control

Advanced Lateral Bound with Balance

Balance and Twist

Basic Lateral Bound with Balance

Catch

Catching Game 2

Basic Catch

Catching Game 1

Advanced Catch

Deep Squat

Deep Squat
Thumb War Game

Achilles Stretch (Ankle Mobility) for Deep Squat

Deep Squat
Cone Reaction Game

Calf/Soleus Stretch for Deep Squat

Bunny Hops

Frog Squat

Project FLAME

Dribble

Advanced Seated Dribble

Basic Dribble

Double Dribble

Cone Dribble

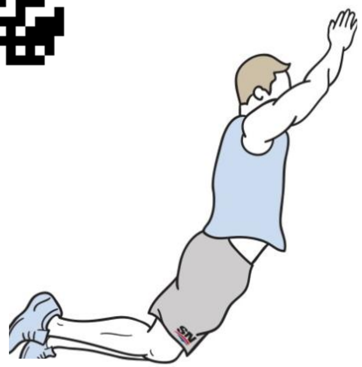
Legs Dribble

Basic Seated Dribble

Horizontal Jump

Horizontal Jump Tag (Group)

Basic Horizontal Jump 01



Horizontal Jump Tag (Pair)

Basic Horizontal Jump 02

In-Line Lunge

Beanbag Lunge 02

Beanbag Lunge 01

Rotary Stability

Superman Standing

Spiderman Rotation 01

Superman Kneeling

Spiderman Rotation 02

Kick

Basic Kick 01

Basic Kick 02

Project FLAME

Run

Exchange

Fun Runs

Running Technique

Left-Foot Strike

Right-Foot Strike

Shoulder Mobility

Windmill

Front and Back

V Slides

Rowing

Wall Slides

Press Up and Pull Down

Wall Angel

Active Straight Leg Raise

Hamstring Assisted Partner Stretch (Doorframe)

Skip

Cone Skip

Basic Marching Technique 01

Basic Marching Technique 02

High Skip

March into Basic Skip

Strike

Basic Strike

Throw

Throwing Game

Basic Throw

Project FLAME

Vertical Jump

Mexican Wave Vertical Jump

Basic Vertical Jump

Clap High Five (Vertical Jump)

Landing Technique and Reaction

Mexican Wave Circle

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The Kinaesthetic Classroom

Movement Breaks

1) Hip Twists	2) Chair Squats
3) Vertical Jump	4) Balance
5) Running and Skipping Technique	6) Lunge
7) Landing Technique	

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Project FLAME

Seomra Ranga Cinéistéiseacha

Sosanna Gluaiseachta

1) Castaí na gCromán

2) Gróigeadh na Cathaoireach

3) Léim Ingearach

4) Cothromaíocht

5) Teicníc Reatha agus Scipeála

6) Áladh Inlíne

7) Teicníc Tuirlingthe